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Of Interest to Managers

Brian Schreier (DWR), brian.schreier@water.ca.gov and Louise Conrad (DWR), louise.conrad@water.ca.gov

This issue of the IEP Newsletter features one contributed paper on water quality from the South Delta region and a diverse set of three Status and Trends articles, ranging from the North Delta (Yolo Bypass fisheries monitoring) to the San Francisco Bay.

In the Contributed Paper, **Rachel Pisor** (DWR, Municipal Water Quality Investigations) details the results from a multi-year study examining the content and effects of storm water discharges from the city of Lathrop into the San Joaquin River. Results indicated concentrations of ammonia, total nitrogen, orthophosphate, and total phosphorus were significantly higher in the effluent compared to the river. Ammonia and total nitrogen loads, however, only made up less than 5% and 1%, respectively, of the total San Joaquin load, though the load increased during first flush events. Concentrations of these constituents in the storm water were similar to values found in other California municipalities.

In the first of the Status and Trends articles, **Jared Frantzich** (DWR, Aquatic Ecology Studies) and colleagues provide an update on WY2012 Yolo Bypass Fisheries Monitoring Program, which has been ongoing since 1998. WY2012 was characterized by the lowest recorded winter and spring flows in the program's history and contrasted strongly with the relatively wet WY2011. Despite low flow conditions, fish monitoring in the Yolo Bypass recorded record high catches of adult and juvenile Delta Smelt and adult White Sturgeon. Catches for both species were almost double the previous record catches for the program. Frantzich and co-authors note that the highest catches for Delta Smelt in the program's history have occurred during relatively dry years. While the reason for this pattern is not known, it is possible that habitat conditions in the Yolo Bypass during these years are favorable to Delta Smelt (e.g., high turbidity, suitable food source). Peak White Sturgeon catch in WY2012 was closely linked with spring flow pulses, strongly suggesting a migratory response to increases in flow.

Additionally in the Status and Trends section, **Lauren Damon** (DFW) reports on the 2012 20 mm Survey. From March-June 2012, this survey collected over 50,000 fish with juvenile Delta Smelt making up 2% of the total (1,077 fish). The first juvenile Delta Smelt were caught in the end of March, indicating spawning began in early March, and subsequent surveys indicated an end to spawning in May. Larval smelt were found in Suisun Marsh, Napa River, and the confluence. The 2012 juvenile Delta Smelt index was 11.1, which is the eighth highest on record.

In a final Status and Trends article, **Paul Buchanan** (USGS) details data on specific conductance and water temperature in the San Francisco Bay for WY2008-2010, collected for compliance with Order 10 of the Water Rights Decision 1485. These data provide the basis for validating many numerical models for the bay that guide both development and restoration projects, and are used for special studies to determine the effect of flow diversions on salinity. Data are presented in time-series graphs at five sites in the bay.

Did you know that quarterly highlights about current IEP science can be found on the IEP webpage along with a new calendar that displays IEP Project Work Team and other IEP-related public meetings? To view these features see the links below:

http://www.water.ca.gov/iep/activities/calendar.cfm
http://www.water.ca.gov/iep/highlights/index.cfm

Contributed Papers

Storm Water Discharges of Nutrients from a Small Community in the Sacramento-San Joaquin River Delta

Rachel Pisor (DES), Rachel.pisor@water.ca.gov

Introduction

Urbanization impacts are a major concern for entities managing or receiving water from the Sacramento-San Joaquin River Delta (Delta). Potentially adverse impacts due to urbanization come from storm water runoff, increases in waste water treatment plant discharges and recreational uses. Storm water contains a variety of contaminants resulting from vehicle maintenance wastes, construction, fertilizers, pesticides, household hazardous wastes, pet wastes, sediment washed off from impervious surfaces, and other anthropogenic sources (Shaver et al. 2007). This study focuses on the impacts of storm water runoff from the city of Lathrop, which had experienced rapid urbanization until the housing market collapse in 2008. During this study, numerous drinking water quality and ecological water quality constituents of concern were monitored; however, the focus of this paper is on nitrogen and phosphorus nutrients.

Nutrients are an essential part of a healthy ecosystem, but adverse effects can occur when levels of nutrients exceed natural background levels. In storm water, a major source of nutrients is lawn and garden fertilizer. Other sources of nutrients include atmospheric deposition, automobile exhaust, soil erosion, animal waste, and detergents. Readily available nutrients, in combination with environmental factors such as warm temperatures and sunlight, can cause algal blooms which can clog up water ways, impede light transmission, and consume oxygen that would otherwise be available for fish and other aquatic wildlife. Ammonia is of particular interest since studies have shown that delta smelt (*Hypomesus transpacificus*), an endangered species that is endemic to the Delta, exhibits symptoms of toxicity from elevated levels of ammonia/ammonium (Connon et al. 2011). Ammonia may also inhibit diatom production which has the potential to reduce productivity, therefore affecting the food chain detrimentally (Wilkerson et al. 2006, Dugdale et al. 2007). The US Environmental Protection Agency (EPA) has developed draft acute and chronic criteria for ammonia (EPA 2009). The criteria at pH 8 and 25 °C, when mussels are absent, is 5.0 mg N/L (acute) and 1.8 mg N/L (chronic).

In addition to ecosystem impacts, higher levels of nutrients may cause drinking water quality issues. The algal blooms resulting from high nutrient levels can cause taste and odor issues, can clog up filters, and can increase the volume and cost of solid waste disposal at water treatment facilities. Although the main concern with nutrients stems from their ecological effects, there are goals for nitrate concentrations based on its ability to cause methemoglobinemia (blue baby syndrome). The EPA has established a maximum contaminant level (MCL) of 10 mg/L for nitrate and 1 mg/L for nitrite which the Central Valley Regional Water Quality Control Board has adopted. The EPA has also developed reference conditions for total nitrogen and total phosphorus for Ecoregion I, which includes the Delta. These reference conditions are 0.31 mg/L for total nitrogen and 0.47 mg/L for total phosphorus (EPA 2001).

The Delta provides drinking water for approximately 25 million Californians; therefore, it is necessary to analyze a broad scale of discharge effects in the system (Delta Stewardship Council 2010). The majority of storm water research pertains to impacts from large dischargers, and there is limited information about the effects from smaller dischargers like the city of Lathrop. As such, this study focuses on the effects of Lathrop's urban runoff during storm events, when Lathrop primarily discharges. Special attention was given to first flush events when it is common to see a higher concentration of contaminants being discharged to the river. This paper focuses on ammonia, nitrate, total nitrogen, orthophosphate and total phosphorus concentrations. Loads for ammonia, total nitrogen and total phosphorus are also discussed.

Site Description

The City of Lathrop is located approximately 53 miles south of Sacramento and 62 miles east of San Francisco.

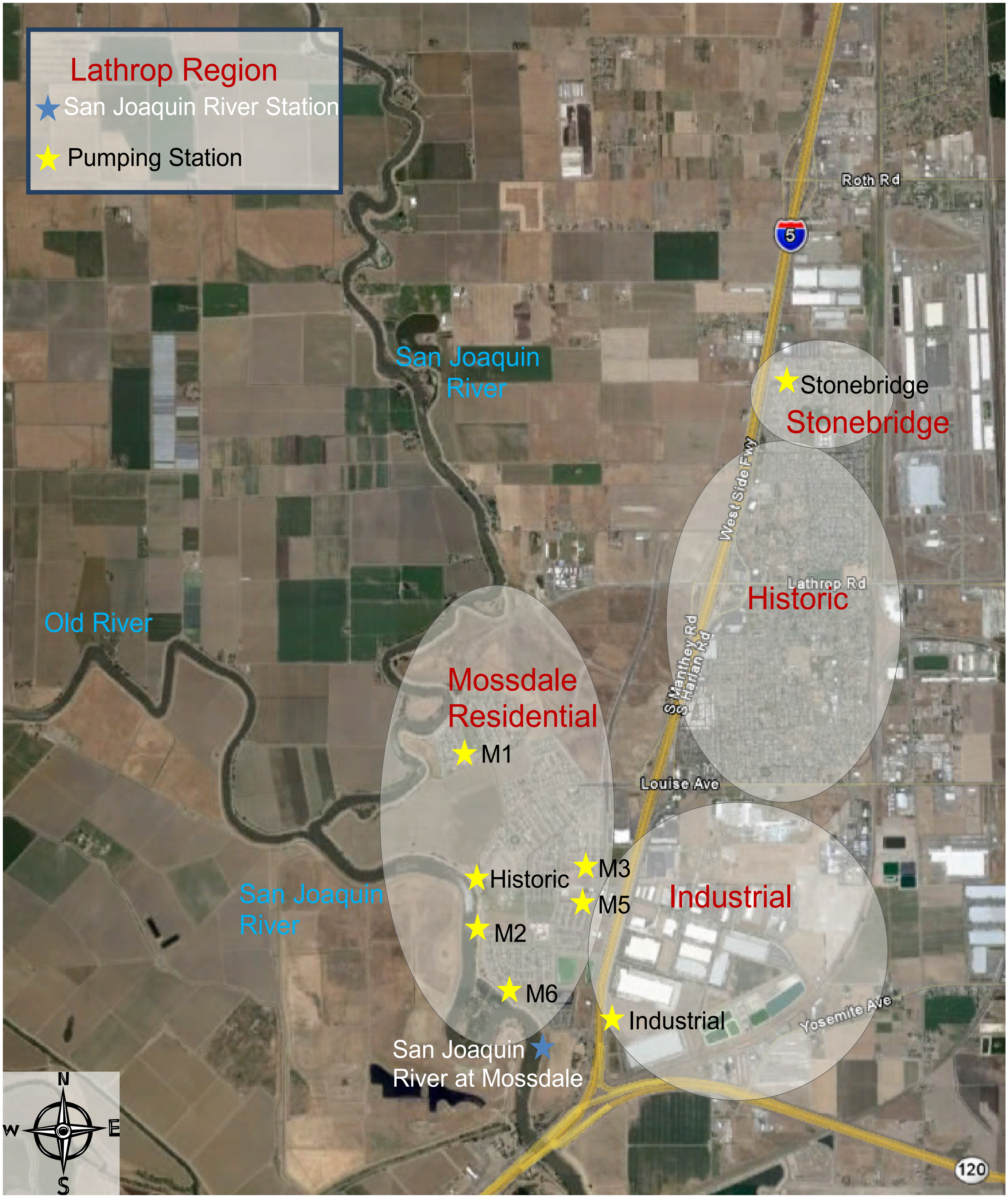

Figure 1 Map of pump stations and regions

The population of the city was 18,023 at the 2010 census. This area is characterized by a Mediterranean climate with cool, wet winters, and warm, dry summers. Due to the flat topography of the area, Lathrop is prone to flooding from the San Joaquin River which flows from the south to the north as it enters the Delta. Due to its proximity to the ocean, the river is weakly tidal in this area. During very strong flood tides, the river can reverse direction, but it primarily has a seaward flow.

The city manages its floodwaters with storm water pumping stations and detention basins. The city has four regions that each handle storm water runoff differently (Figure 1). The Industrial Region and the Stonebridge Region (a relatively new development) both have a detention basin and a pumping station. The Historic Region, which represents the original town, has no in-ground storm sewer. Runoff is collected in detention basins and is then channeled to the Louise pumping station which then pumps the water to the Historic pumping station on the other side of town. The Historic pumping station is where this study collected samples because it discharges directly to the San Joaquin River. The Mossdale Residential Region is a new development and has five pumping stations to handle the storm water. The area of the city of Lathrop is approximately 21.9 mi^2 which is only 0.1% of the San Joaquin River watershed (17,720 mi^2) (SWAMP 2004). Currently, 20% of Lathrop's area is drained by the pumping stations (4.35 mi^2) although this will expand with future development. The San Joaquin River watershed is highly agricultural, with approximately 2.0 million acres in agriculture. This agricultural area represents 23% of the total irrigated acreage in California (SWAMP 2009). The land uses of Lathrop are approximately 57% open space or agricultural and 43% urban.

Lathrop is an ideal study site due to its small size and location in the southern Delta. It also represents a simple system; the city's discharge is the only discharge in the local stretch of the San Joaquin River. Although the discharge from Lathrop is small, its effects on Delta drinking water quality have the potential to be significant due to Lathrop's location.

Materials and Methods

Sampling for this study took place over two rainy seasons, from October 2010 through September 2012. Data were collected during first flush and major storm events where a threshold of 0.5 inches of precipitation occurred within a 24 hour period. The 0.5 inch threshold was used as a guideline, and some smaller storms were sampled. While sampling events were geared toward major storm events, not all major events were sampled due to inaccuracies in weather forecasting. Over the course of the two seasons, 10 storm events were sampled (Figure 2).

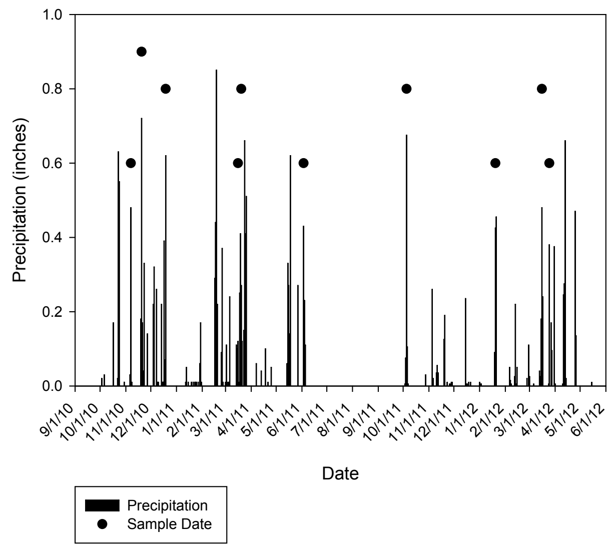

Figure 2 Precipitation and sample dates, seasons 1 and 2

Flow data was collected to allow for the calculation of nutrient loads (the mass of the nutrient in the system). San Joaquin River flow data was obtained from the California Department of Water Resources (DWR). Flow estimates from the city pumping stations were obtained from MCC Control Systems, Inc. (MCC) and were approximated from pumping volumes.

Samples were collected from the San Joaquin River and from the eight pumping stations that discharge directly to the river. Samples collected from the San Joaquin River were collected as grab samples and represent a snapshot in the middle of the storm. These samples were collected upstream of Lathrop's discharges and were collected during an ebb tide to ensure a sample representative of the background quality of the San Joaquin River. Autosamplers were used to collect samples from the city pumping stations throughout a storm event. Autosamplers were connected to Lathrop's Supervisory Control and Data Acquisition (SCADA) system which monitors the pumps. When the pumps started pumping due to an inflow of storm water, they triggered the autosamplers to start sampling. Occasionally there were signal errors between the SCADA system and autosamplers, resulting in a lost sample. Sometimes a sampler would not collect enough sample water to process all constituents due to an underestimation of how much a pump would discharge during the storm. This lack of sample water resulted in variation of how many samples were collected from each pump station.

All samples were analyzed for dissolved ammonia, Kjeldahl nitrogen, nitrate, nitrate plus nitrite, orthophosphate, and total phosphorus. Total nitrogen was calculated as the sum of Kjeldahl nitrogen, nitrate, and nitrite.

Loads were analyzed for ammonia, total nitrogen and total phosphorus as a function of flow and TOC concentration. The load for the San Joaquin River was an instantaneous load; the median river flow for the storm was multiplied by the concentration of the grab sample taken at the San Joaquin River at Mossdale. Loads for the pumping stations used the pump data collected from the storm water pumps. These pumps operate sporadically, turning on when a set level of water in the well is reached, and turn off when the water drops below a set level. Because this flow rate is not constant, the load is calculated as the gallons of water pumped over the course of the storm. To ensure comparability of load between the pumping stations and the river, the San Joaquin River load was then multiplied by a conversion factor to approximate the total load discharged from the river during the storm.

Results

Ammonia Concentrations

For seasons 1 and 2, the concentrations on the San Joaquin River were significantly lower than the combined city pumping station concentrations (Mann-Whitney, $p=0.001$). One sample was below the reporting limit; half of the reporting limit was used in the test. The median values for the city pumping stations over the two seasons ranged from 0.31 mg/L to 0.65 mg/L. The range of concentrations from the city pumping stations was 0.01 mg/L to 2.4 mg/L. Over the two seasons, the concentrations from the Industrial station were relatively low, and the concentrations in the Mossdale residential region were somewhat variable (Table 1). The concentrations from the Historic station were generally higher, with an unusually high outlier of 2.4 mg/L as nitrogen (mg/L as N). This station serves the historic part of the city, which does not have a built-in storm sewer system and serves the largest area of all the pumping stations. The cause for this high concentration is potentially due to a residential fertilizer application just prior to the storm event in the historic region of the city. City of Lathrop staff confirmed that there was no ammonia-containing spill that could have contributed to this high concentration (Milt Daley personal communication, see “notes”).

Table 1 Summary statistics for dissolved ammonia, seasons 1 and 2, in mg/L as N

Station	*Total samples*	*Mean*	*Median*	*Min*	*Max*	*Standard Deviation*
M1	8	0.32	0.31	0.09	0.68	0.19
M2	10	0.42	0.41	0.04	0.77	0.25
M3	10	0.52	0.42	0.23	1.00	0.26
M5	4	0.51	0.48	0.36	0.73	0.16
M6	8	0.33	0.32	0.16	0.58	0.14
Historic	9	0.78	0.65	0.19	2.40	0.64
Industrial	7	0.30	0.32	0.01	0.46	0.14
SJR at Mossdale	10	0.03	0.02	<R.L.	0.07	0.02

When the concentrations were analyzed by year, the concentrations on the San Joaquin River at Mossdale were significantly lower than the concentrations of the city pumping stations for both years (Mann-Whitney, $p<0.001$ for season 1, $p=0.002$ for season 2). There was no statistical difference in the city pumping stations or in the San Joaquin River concentrations between years, even though one year was classified as wet, and the other dry. The patterns between the pumping stations were very similar for all of the stations, except for the outlier previously mentioned at the Historic station in season 2. Trends for ammonia over the two seasons are unclear. In season 1, ammonia concentrations showed evidence of a first flush effect in which the first storm sampled had the highest median concentration; however, this was not the case for season 2.

Ammonia Loads

Ammonia loads during storm events in season 1 were quite variable (Table 2). In season 1, most loads from Lathrop made up less than 6% of the total load on the San

Joaquin River. The exception was during the 11/20/2010 storm event in which Lathrop made up 14.7% of the river's total load. A comparison of ammonia concentrations between the stations showed that Lathrop's concentrations during the 11/20/10 event were not abnormally high. For example, during the 11/7/10 event, many of the pumping stations had higher concentrations than during the 11/20/10 event. However, during the 11/20/10 event, the storm was nearly twice the volume of the 11/7/10 event, and Lathrop discharged approximately twice of what it did during the 11/7/10 event. Therefore, the increased discharge from Lathrop is responsible for the increase in load. This was coupled with low flows and, consequently, low load on the San Joaquin River.

During the second season, the ammonia loads were generally higher for each storm (Table 2). During the first flush event of the second season, the ammonia concentration on the San Joaquin River was below the reporting limit. As a result, Lathrop may have contributed most of the ammonia in the system during that storm. This increase in loads during season 2 is likely due to the effects of a dry water year as season 1 was during a wet year. In season 2, the flows were generally lower, and the San Joaquin River generally carries a low ammonia load. The low background ammonia load in the San Joaquin River may be due to bacteria converting ammonia to nitrate in the water. For both seasons, all concentrations sampled at the pumping stations were below the draft acute and chronic criteria developed by the EPA for water bodies that do not contain mussels, with the exception of the sample from the Historic station that was 2.4 mg/L as N.

Dissolved Nitrate

For dissolved nitrate, there were no statistical differences between the San Joaquin River and the city pumping stations in seasons 1 or 2 (Table 3). In fact, the San Joaquin River at Mossdale samples had relatively higher concentrations than several of the city pumping stations (Table 3). With the exception of the M1 station, the Mossdale residential stations and the Historic station all had relatively low concentrations of nitrate. The medians for all stations ranged from 2.4 mg/L as N to 5.6 mg/L as N and the overall range of concentrations was from 1.2 mg/L as N to 16.6 mg/L as N.

There was no statistical difference in concentrations between seasons 1 and 2; however, the patterns between the two years have some differences (Table 3). The concentrations on the San Joaquin River at Mossdale increased slightly from season 1 to season 2. The M1 and Industrial stations had some elevated concentrations from season 1 to season 2 although the maximum concentrations for these stations did not reflect this. The M1 station still had the largest range of all stations. There were no seasonal trends for dissolved nitrate.

Table 2 Ammonia loads (in kg discharged per storm), seasons 1 and 2

	Date of Storm Event- Season 1					
Station	***11/7/10***	***11/20/10***	***12/18/10***	***3/19/11***	***3/24/11***	***6/5/11***
M1	N/A	3.12	0.81	0.58	1.12	0
M2	2.00	5.78	3.14	1.93	2.90	0.76
M3	1.33	2.31	1.10	1.33	1.12	0.82
M6	0.19	N/A	0.26	0.24	0.30	0.15
Historic	2.07	5.07	3.10	N/A	1.20	6.18
Industrial	N/A	7.78	5.78	0	0	1.70
SJR at Mossdale	89.72	139.47	639.72	.63	2,263.03	439.62
Lathrop's %	5.9%	14.7%	2.2%	<1%	<1%	2.1%
Lathrop's total	5.59	24.06	14.19	4.07	6.68	9.60

	Date of Storm Event- Season 2			
Station	***10/5/11***	***1/20/11***	***3/14/12***	***3/24/12***
M1	1.48	2.14	1.34	0.28
M2	0.28	3.28	1.87	3.91
M3	1.21	10.79	1.09	0.38
M5	0.49	3.07	0.51	0.35
M6	0.24	0.44	0.24	0
Historic	5.60	7.64	2.01	1.47
Industrial	0.23	7.74	<0.01	0.10
SJR at Mossdale	<R.L.	313.85	50.72	36.55
Lathrop's %	N/A	10.1%	12.2%	15.1%
Lathrop's total	9.54	35.12	7.07	6.49

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or that there was a communication problem with the SCADA resulting in no sample and pump data. <R.L. indicates the concentration was below the reporting limit. Load from the pump stations is listed as total kilograms discharged during the storm. Load at the SJR at Mossdale station is calculated as an instantaneous load and is converted to kilograms discharged during the storm.

Table 3 Summary statistics for dissolved nitrate seasons 1 and 2, as mg/L as N

Station	Number of samples	Mean	Median	Min	Max	Standard Deviation
Seasons 1 and 2						
M1	8	7.0	4.9	2.3	16.6	5.8
M2	10	6.7	5.6	2.9	12.3	3.6
M3	10	3.0	2.4	1.2	8.8	2.2
M5	4	2.6	2.6	1.7	3.8	0.9
M6	8	2.7	2.5	1.8	3.9	0.8
Historic	9	3.5	3.0	1.5	5.8	1.5
Industrial	7	5.8	5.1	2.5	10.6	3.1
SJR at Mossdale	4	5.4	5.6	1.8	10.6	3.3
Season 1						
M1	4	6.7	4.6	2.3	15.4	6.0
M2	6	8.2	8.6	3.8	12.3	3.8
M3	6	3.1	2.0	1.2	8.8	2.9
M6	5	3.0	2.9	2.0	3.9	0.9
Historic	5	3.8	4.6	1.5	5.8	2.2
Industrial	3	5.5	3.5	2.5	10.6	4.4
SJR at Mossdale	6	3.4	2.1	1.8	9.0	3.1
Season 2						
M1	4	7.2	4.9	2.5	16.6	6.4
M2	4	4.4	4.0	2.9	6.4	1.6
M3	4	2.9	2.5	2.3	4.4	1.0
M5	4	2.6	2.6	1.7	3.8	0.9
M6	3	2.2	2.0	1.8	2.8	0.5
Historic	4	3.0	2.7	1.9	4.8	1.3
Industrial	4	5.9	6.0	2.9	8.9	2.5
SJR at Mossdale	4	7.3	6.9	4.8	10.6	2.4

Total Nitrogen

Total Nitrogen was calculated as a sum of Kjeldahl nitrogen and dissolved nitrate plus nitrite. Total nitrogen samples for seasons 1 and 2 from the San Joaquin River at Mossdale were significantly lower than samples taken at the city pumping stations (Table 4; Mann-Whitney, $p=0.011$). Overall, the M6 pumping station and the Industrial station had low concentrations. There was much variability throughout the other stations in the Mossdale residential region, and the Historic station also had a wide range of concentrations. The median city pumping station concentrations ranged from 1.66 mg/L as N to 4.53 mg/L as N. The range of concentrations for the city pumping stations ranged from 0.62 mg/L as N to 11.20 mg/L as N (Table 4). These concentrations are significant compared to the recommended EPA criteria for total nitrogen of 0.31 mg/L as N (EPA, 2001).

Table 4 Summary statistics for total nitrogen, seasons 1 and 2, as mg/L as N

Station	Number of samples	Mean	Median	Min	Max	Standard Deviation
Seasons 1 and 2						
M1	8	2.66	2.02	1.52	5.70	1.46
M2	10	4.32	2.85	1.88	11.20	3.38
M3	10	3.13	1.77	0.62	9.57	3.38
M5	4	3.48	1.86	1.48	8.73	3.51
M6	8	1.72	1.66	1.10	2.39	0.49
Historic	9	6.23	4.53	1.78	11.20	4.00
Industrial	7	2.12	2.10	1.10	3.20	0.76
SJR at Mossdale	4	1.59	1.50	0.49	3.40	0.90
Season 1						
M1	4	2.32	1.88	1.52	4.00	1.14
M2	6	4.19	3.40	2.06	9.87	2.91
M3	6	2.67	1.42	0.62	9.42	3.34
M6	5	1.72	1.85	1.10	2.24	0.50
Historic	5	5.48	3.00	1.78	10.40	4.33
Industrial	3	2.01	1.72	1.10	3.20	1.08
SJR at Mossdale	6	1.18	1.01	0.49	2.10	0.69
Season 2						
M1	4	2.99	2.32	1.63	5.70	1.85
M2	4	4.51	2.48	1.88	11.20	4.48
M3	4	3.83	2.00	1.76	9.57	3.83
M5	4	3.48	1.86	1.48	8.73	3.51
M6	3	1.72	1.46	1.30	2.39	0.59
Historic	4	7.18	7.18	3.15	11.20	3.93
Industrial	4	2.21	2.25	1.44	2.90	0.61
SJR at Mossdale	4	2.20	2.05	1.30	3.40	0.92

There was no significant difference in total nitrogen concentrations between seasons 1 and 2. In season 1, the San Joaquin River at Mossdale concentrations were significantly lower than the city pumping station concentrations (Mann-Whitney, $p=0.009$); however, they were not significantly different in season 2. The reason why the second season did not show a significant difference in concentrations between the city pumping stations and the

San Joaquin River may be due to the small sample size, but it is also likely that it is a result of wet year versus dry year effects. The overall pattern of data between season 1 and 2 is similar, although the M2 and M3 stations had a much broader data distribution in season 2 (Figures 3 and 4). The M5 station was not sampled in season 1 due to forecasting issues and problems with the signal between the SCADA system and autosampler. However, in season 2, the M5 station was sampled and had wide range of concentrations (Table 4). Although there were no significant trends for nitrate, and unclear trends for ammonia, there was a decreasing trend for total nitrogen concentrations, indicating a first flush effect. In each season, the first storm event sampled had medians that were significantly higher than those in the following storms.

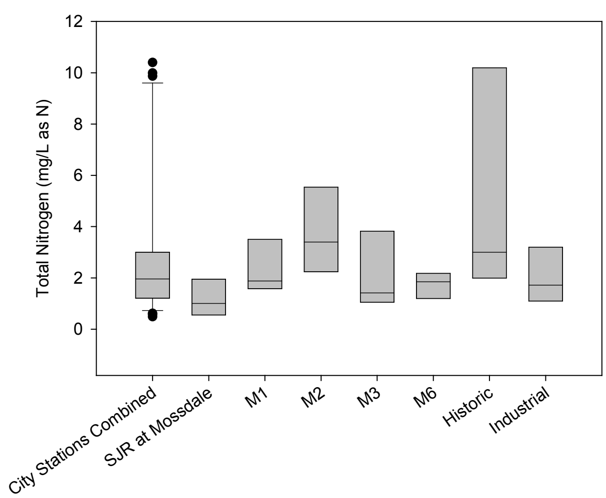

Figure 3 Boxplot of total nitrogen for season 1

Total Nitrogen Loads

Although the concentrations for the city of Lathrop were significantly higher than the San Joaquin River for season 2, and for seasons 1 and 2 combined, the city did not contribute a significant load to the San Joaquin River (Table 5). For season 1, the city's portion of the total nitrogen load on the San Joaquin River was less than 1% for all storms. In season 2, the city's total nitrogen concentrations were not significantly different from those sampled on the San Joaquin River, and the total load contributed by the city was also insignificant. With the exception of the first flush event in season 2 in which the city contributed 1.5% of the total load on the San Joaquin River, the city contributed less than 1% of the load throughout the storm season.

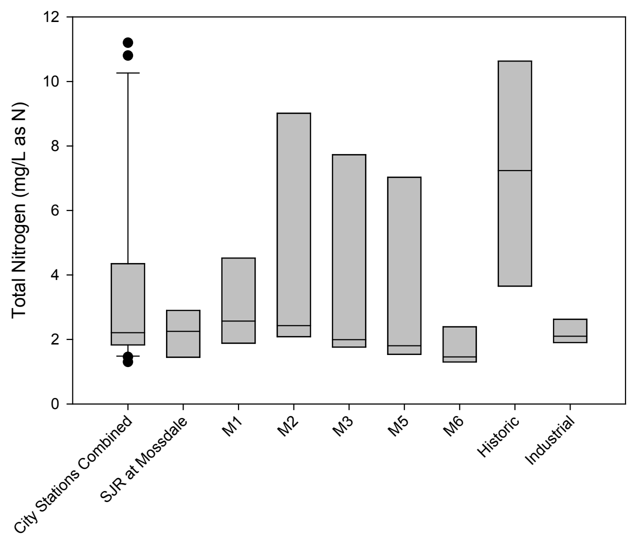

Figure 4 Boxplot of total nitrogen for season 2

Orthophosphate

Orthophosphate concentrations for seasons 1 and 2 on the San Joaquin River were significantly lower than those in the city pumping stations (Mann-Whitney, $p=0.047$). The samples from the San Joaquin River at Mossdale had a reasonably large range of values that overlapped many of the city pumping stations values. Of all the city pumping stations, the Historic station had the widest variability. The median values for the city pumping stations ranged from 0.07 mg/L as P to 0.16 mg/L as P and the range of city pumping station concentrations was from 0.03 mg/L as P to 0.27 mg/L as P (Table 6).

There was no significant difference in orthophosphate concentrations between seasons 1 and 2. In season 1, the San Joaquin River at Mossdale concentrations were significantly lower than the city pumping station samples (Mann-Whitney, $p=0.015$). There was no significant difference in concentrations between the city pumping stations and the San Joaquin River at Mossdale station for Season 2; however, the patterns of the data were quite different between seasons. The concentrations for the San Joaquin River at Mossdale increased from season 1 to season 2 (Table 6). The Mossdale residential region data was more tightly clustered in season 1 than season 2. As a result, the data appears to show more variation for the region. The Historic station changed the most from season 1 to 2, showing a much wider range of concentrations in season 2. The Industrial station did not show significant change from season 1 to 2 (Figures 5 and 6). These differences in data between seasons 1 and 2 may be due to wet versus dry water year effects. There were no significant trends over the two year period.

Table 5 Total nitrogen load (in kg discharged per storm)

Season 1-Date of Storm Event						
Station	***11/7/10***	***11/20/10***	***12/18/10***	***3/19/11***	***3/24/11***	***6/5/11***
M1	N/A	12.80	4.27	6.34	49.77	0
M2	27.05	32.89	15.41	16.44	67.57	9.48
M3	13.34	6.48	3.29	5.50	3.12	2.94
M6	0.85	N/A	1.91	1.08	2.92	0
Historic	31.77	38.01	16.31	N/A	11.32	1.24
Industrial	N/A	18.58	24.85	0	0	91.81
SJR at Mossdale	9,420.37	13,249.68	15,673.35	28,234.99	39,118.06	27,815.77
Lathrop's percentage	<1%	<1%	<1%	<1%	<1%	<1%
Lathrop's total	73.00	108.76	66.04	29.44	134.70	126.27

Season 2- Date of Storm Event				
Station	***10/5/11***	***1/20/12***	***3/14/12***	***3/24/12***
M1	164.76	17.70	17.01	1.82
M2	44.67	12.36	14.98	42.61
M3	14.74	24.82	6.32	2.05
M5	3.81	12.61	2.99	1.25
M6	1.87	1.53	1.27	N/A
Historic	46.37	20.85	15.94	5.52
Industrial	156.92	215.38	0.04	1.76
SJR at Mossdale	27,593.10	57,277.45	32,968.73	12.914.26
Lathrop's percentage	1.5%	<1%	<1%	<1%
Lathrop's total	433.15	305.25	58.55	55.01

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Table 6 Summary statistics orthophosphate, seasons 1 and 2, as mg/L as P

Seasons 1 and 2						
Station	***Number of samples***	***Mean***	***Median***	***Min***	***Max***	***Standard Deviation***
M1	8	0.17	0.16	0.12	0.25	0.04
M2	10	0.12	0.12	0.06	0.18	0.04
M3	10	0.07	0.07	0.03	0.10	0.02
M5	4	0.09	0.09	0.06	0.12	0.03
M6	8	0.13	0.11	0.09	0.21	0.04
Historic	9	0.15	0.14	0.06	0.27	0.08
Industrial	7	0.12	0.13	0.06	0.17	0.04
SJR at Mossdale	4	0.09	0.08	0.02	0.17	0.05
Season 1						
M1	4	0.15	0.16	0.12	0.18	0.03
M2	6	0.11	0.12	0.08	0.15	0.03
M3	6	0.07	0.07	0.03	0.10	0.02
M6	5	0.14	0.12	0.09	0.21	0.05
Historic	5	0.16	0.16	0.06	0.27	0.11
Industrial	3	0.11	0.13	0.06	0.15	0.05
SJR at Mossdale	6	0.07	0.07	0.02	0.12	0.03
Season 2						
M1	4	0.18	0.17	0.14	0.25	0.05
M2	4	0.13	0.13	0.06	0.18	0.05
M3	4	0.07	0.08	0.03	0.10	0.03
M5	4	0.09	0.09	0.06	0.12	0.02
M6	3	0.12	0.10	0.10	0.17	0.04
Historic	4	0.14	0.14	0.12	0.18	0.03
Industrial	4	0.12	0.13	0.06	0.17	0.05
SJR at Mossdale	4	0.12	0.13	0.07	0.17	0.04

Total Phosphorus

For seasons 1 and 2 combined, the concentrations on the San Joaquin River at Mossdale were significantly lower than the concentrations sampled from the city pumping stations (Mann-Whitney, $p=0.001$). There was much variability in concentrations throughout the Mossdale Residential Region (M stations) with M2 and M3 having the widest range of concentrations (Table 7). The M3 station also had the lowest concentration of all stations. Samples collected from the M6 and Historic stations were generally high. The Industrial station concentrations were generally in the middle of the range of all concentrations. The median concentrations for the city pumping stations ranged from 0.14 mg/L as P to 0.37 mg/L as P.

The median of 0.14 mg/L as P was lower than that of the San Joaquin River (0.16 mg/L as P), showing that the San Joaquin River concentrations were not dramatically lower than those in the city pumping stations. The overall range of concentrations was from 0.05 mg/L as P to 0.48 mg/L as P. These concentrations are relatively low and generally under the EPA criteria of 0.47 mg/L as P.

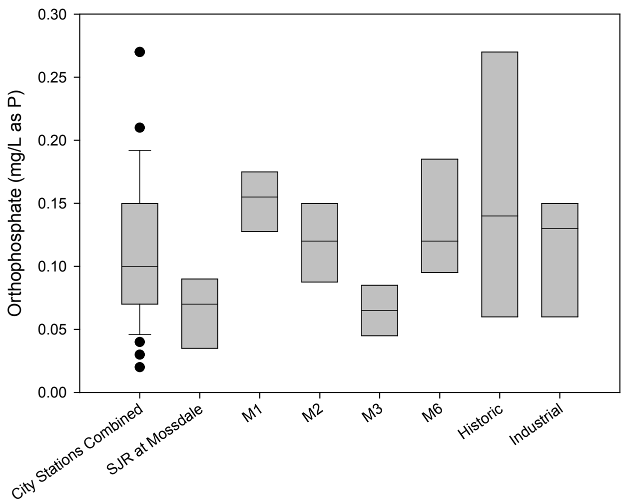

Figure 5 Boxplot of Orthophosphate for Season 1

Unlike orthophosphate, there was a significant difference in total phosphorus concentrations between season 1 and season 2, with season 1 concentrations being significantly lower than season 2 samples (Mann-Whitney, p=0.016). There was a significant difference in total phosphorus concentrations between the San Joaquin River and the city pump stations in season 1 (Mann-Whitney, p= 0.009), but not for season 2. The data patterns also differed slightly from season 1 to 2 (Figures 7 and 8). In season 1, the data for each station was more tightly clustered and there was more variation between stations. In season 2, the data for each station was more spread out, the concentrations at the M3 and Industrial stations increased, and there was more overlap of concentrations from the city pumping stations with the San Joaquin River at Mossdale concentrations. Except for the Industrial station, all medians for the stations increased from season 1 to season 2. The ranges also increased between seasons 1 and 2 (Table 7). These differences in water quality may be due to wet water year (season 1) versus dry water year (season 2) effects. There was also a slight trend in both seasons for total phosphorus, with higher concentrations during the first storm of each season. This result indicates that there was a first flush effect.

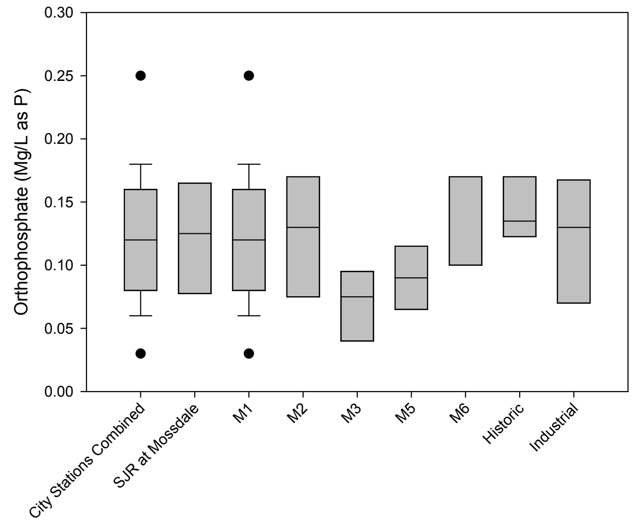

Figure 6 Boxplot of Orthophosphate for Season 2

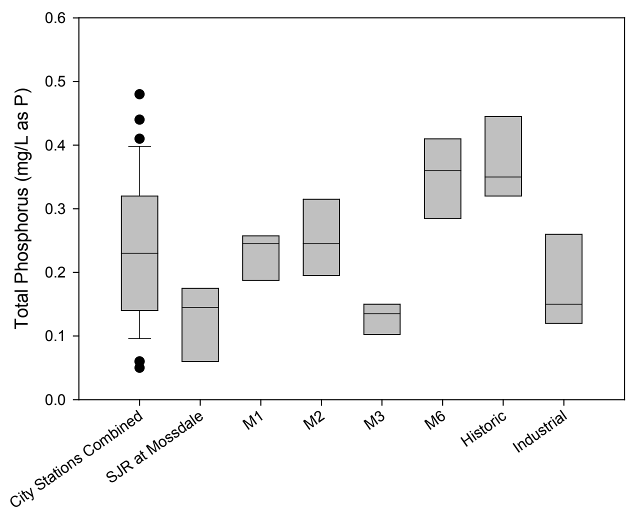

Figure 7 Boxplot of total phosphorus for season 1

Total Phosphorus Load

The San Joaquin River had total phosphorus concentrations that were significantly lower than the city stations for season 1, and seasons 1 and 2 combined; however, the levels did not significantly impact the total load on the San Joaquin River. In season 1, Lathrop contributed a maximum of 1% of the total load on the river for every storm sampled. In season 2, Lathrop contributed 2.7% during the first storm and 1.5% during the second storm, but contributed less than 1% for the remaining storms in the season (Table 8). It is likely that Lathrop contributed more in the first two storms because they were both flush events. The 10/5/2011 storm (season 1) was the first storm after a long, dry summer. The storm on 1/20/2012 was also preceded by a long dry period.

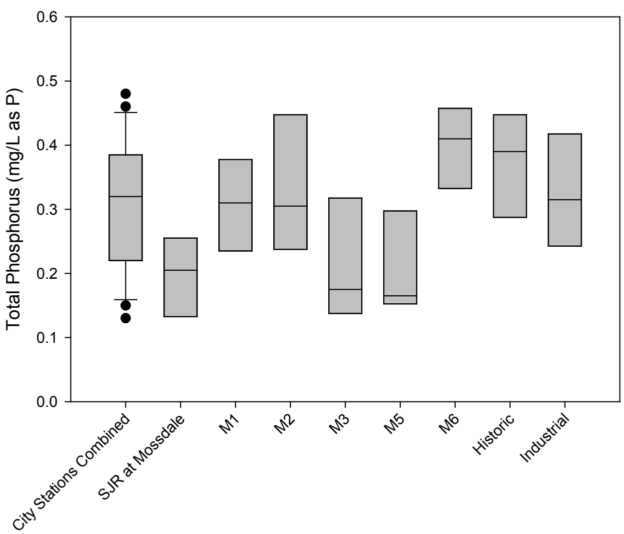

Figure 8 Boxplot of total phosphorus for season 2

Discussion

Ammonia Concentrations

Throughout this study, the median concentration on the San Joaquin River at Mossdale was 0.04 mg/L as N, and the maximum concentration was 0.07 mg/L as N. These concentrations were very comparable to what was sampled in the Steelhead Creek Study (DWR 2008). The median concentration in Steelhead Creek during storm events sampled was 0.04 mg/L. These concentrations were also comparable to the storm water samples that the Sacramento Cooperative Monitoring Program (Sacramento CMP) collected on the Sacramento River. Of the four storm events sampled in the 2011-2012 wet season, the means were all 0.04 mg/L with the exception of the 2/29/2012 sampling event in which ammonia sampled at Veteran's Bridge was 0.15 mg/L, and the concentration at Freeport was 0.18 mg/L (medians for the Sacramento CMP were not reported).

Table 7 Summary statistics for total phosphorus, seasons 1 and 2, as mg/L as P

Station	Number of samples	Mean	Median	Min	Max	Standard Deviation
Seasons 1 and 2						
M1	8	0.27	0.26	0.17	0.39	0.07
M2	10	0.29	0.26	0.15	0.48	0.10
M3	10	0.16	0.14	0.05	0.36	0.08
M5	4	0.20	0.16	0.15	0.34	0.09
M6	8	0.38	0.38	0.28	0.46	0.07
Historic	9	0.38	0.35	0.27	0.48	0.07
Industrial	7	0.26	0.26	0.12	0.45	0.11
SJR at Mossdale	10	0.16	0.17	0.06	0.26	0.07
Season 1						
M1	4	0.23	0.25	0.17	0.26	0.04
M2	6	0.26	0.25	0.15	0.39	0.08
M3	6	0.13	0.14	0.05	0.18	0.04
M6	5	0.35	0.36	0.28	0.44	0.07
Historic	5	0.38	0.35	0.32	0.48	0.07
Industrial	3	0.18	0.15	0.12	0.26	0.07
SJR at Mossdale	6	0.13	0.14	0.06	0.19	0.06
Season 2						
M1	4	0.31	0.31	0.22	0.39	0.07
M2	4	0.33	0.31	0.23	0.48	0.11
M3	4	0.21	0.18	0.13	0.36	0.10
M5	4	0.21	0.17	0.15	0.34	0.09
M6	4	0.40	0.41	0.32	0.46	0.07
Historic	4	0.38	0.39	0.27	0.45	0.09
Industrial	4	0.33	0.32	0.22	0.45	0.09
SJR at Mossdale	4	0.20	0.20	0.12	0.26	0.06

Concentrations from the city pumping stations in Lathrop had medians that ranged from 0.31 mg/L as N to 0.65 mg/L as N. These concentrations were comparable to concentrations found by the California Urban Water Agencies (CUWA) in their Urban Runoff Source Control Evaluation (CUWA 2011). In the evaluation, CUWA analyzed data collected from four drainage areas in the Sacramento Area (Strong Ranch Slough, sump 104, sump 111, and Natomas Basin). These areas drained a total of approximately 6,400 acres. Strong Ranch Slough drained mixed land uses, sump 104 drained primarily light industrial land uses, sump 111 drained industrial lands, and the Natomas basin drained primarily residential lands. The medians of the wet weather events for each of these areas were generally higher than those from the city pumping stations. The median ammonia concentrations from CUWA's evaluation ranged from 0.40 mg/L as N to 0.60 mg/L as N.

Table 8 Total phosphorus load (in kg discharged per storm)

	Season 1-Date of Storm Event					
Station	**11/7/10**	**11/20/10**	**12/18/10**	**3/19/11**	**3/24/11**	**6/5/11**
M1	N/A	1.82	0.67	0355	3.24	0
M2	1.07	2.33	1.94	1.07	5.07	0.55
M3	0.25	0.43	0.39	0.41	0.25	0.34
M6	0.15	N/A	0.38	0.28	0.60	0.27
Historic	1.30	4.43	2.36	N/A	2.04	4.24
Industrial	N/A	2.53	1.73	0	0	1.70
SJR at Mossdale	583.16	1,185.50	1,919.19	5,647.00	6,142.51	2,877.49
Lathrop's percentage	<1%	1%	<1%	<1%	<1%	<1%
Lathrop's total	2.78	11.54	7.48	2.31	11.19	7.08

	Season 2- Date of Storm Event			
Station	**10/5/11**	**1/20/12**	**3/14/12**	**3/24/12**
M1	3.87	1.07	1.13	0.16
M2	3.35	1.49	1.22	2.00
M3	1.21	2.05	0.40	0.11
M5	0.34	0.68	0.23	0.11
M6	0.30	0.35	0.26	0.08
Historic	4.35	3.82	2.85	0.50
Industrial	5.08	10.89	<0.01	0.11
SJR at Mossdale	689.83	1,333.86	1318.75	292.40
Lathrop's percentage	2.7%	1.5%	<1%	<1%
Lathrop's total	18.5	20.35	6.10	3.06

Note: A "0" load means the station did not discharge. N/A means the autosampler did not sample or there was a communication problem with the SCADA resulting in no sample and pump data. Load from the pump stations was calculated as total kilograms discharged during the storm. Load at the SJR at Mossdale station was calculated as an instantaneous load and was converted to total kilograms discharged during the storm.

Lathrop's concentrations were also compared with seven drainage areas monitored in the 2011-2012 wet season for the Los Angeles Phase I NPDES permit (Los Angeles County 2012). These areas drained a total of 1,318,400 acres. Like the CUWA evaluation, the Los Angeles median values overlapped those of Lathrop (0.31 mg/al as N to 0.65 mg/L as N). The wet weather median values collected for the NPDES permit ranged for 0.16 mg/L as N to 0.94 mg/L as N.

The result of comparing ammonia concentrations sampled during the Lathrop study with other studies shows that although Lathrop does discharge a considerable amount of ammonia to the San Joaquin River during storm events; however, the concentrations are not significantly higher than those seen for other studies in the Central Valley or Los Angeles. The exception to this was the 2.4 mg/L as N sample collected from the Historic station.

Dissolved Nitrate

When the San Joaquin River nitrate concentrations were compared to those of the Sacramento River collected by the Sacramento CMP, the San Joaquin River concentrations were elevated. The Sacramento River concentrations ranged from 0.04 mg/L as N to 0.54 mg/L as N whereas the San Joaquin River concentrations ranged from 1.8 mg/L as N to 10.6 mg/L as N. This difference in concentration between the two rivers is largely due to the increased amount of agriculture lands that the San Joaquin River drains. Agricultural drainage contains more nutrients such as nitrate due to fertilizer use (EPA 2005).

Lathrop concentrations were slightly low in comparison to those collected in the Steelhead Creek study (DWR 2008). Samples collected during storm events in the Steelhead Creek study had a mean of 5.0 mg/L as N, a median of 4.2 mg/L as N, and ranged from 1.8 mg/L as N to 22.8 mg/L as N. Lathrop concentrations had means ranging from 2.6 mg/L as N to 7.0 mg/L as N, medians from 2.4 mg/L as N to 5.6 mg/L as N, and the range of all concentrations was from 1.2 mg/L as N to 16.6 mg/L as N. The median concentrations analyzed in the CUWA urban sources evaluation were very similar to those sampled in Lathrop (CUWA 2011). The medians in the CUWA evaluation ranged from 0.45 mg/L as N to 2.2 mg/L as N. Lathrop's concentrations were also comparable when compared to the samples collected by Los Angeles for the Phase I NPDES permit (Los Angeles County 2012). The concentrations during the 2011-2012 wet season had medians that ranged from 0.85 mg/L as N to 3.0 mg/L as N. These comparisons show that Lathrop's nitrate discharge concentrations were not unusually high compared to other studies throughout California; however, the concentrations were not necessarily low. Approximately 10% of the samples (7 samples) over the course of the study had nitrate concentrations that exceeded the EPA MCL of 10 mg/L as N.

Total Phosphorus

Lathrop's total phosphorus concentrations were similar to other studies throughout California. The San Joaquin River had significantly lower concentrations throughout the study. In comparison to samples taken on the Sacramento River by the Sacramento CMP, the San Joaquin River concentrations were higher. The San Joaquin River concentrations ranged from 0.06 mg/L as P to 0.26 mg/L as P. All the storm samples collected on the Sacramento River were less than 0.06 mg/L as P with the exception of one 0.53 mg/L as P sample. These differences in total phosphorus concentrations reflect differences in water quality between the Sacramento and San Joaquin Rivers. The San Joaquin generally has higher phosphorus concentrations as a result of agricultural fertilizers.

Lathrop's discharge concentrations were comparable to other studies throughout California. Lathrop's median concentration of 0.26 mg/L as P was lower than the median concentration of 0.34 mg/L as P in the Steelhead Creek Study (DWR 2008). Lathrop's median concentration of 0.26 mg/L as P was comparable to the means of the 4 drainage areas evaluated in CUWA's urban runoff sources and control evaluation (CUWA 2011). The means of these four drainage areas ranged from 0.26 mg/L as P to 0.54 mg/L as P. Lathrop's concentrations were also comparable to storm samples collected for the Los Angeles NPDES annual report for 2010-2011 (Los Angeles County 2012). Los Angeles median concentrations ranged from 0.15 mg/L as P to 0.43 mg/L as P as compared to Lathrop median ranges for all station of 0.26 mg/L as P to 0.46 mg/L as P. These comparisons illustrate that Lathrop's discharge concentrations are not unusually high as compared to other studies in the state.

Conclusion

Dissolved ammonia concentrations on the San Joaquin River were significantly lower than those of the city pumping stations. The Historic station had generally higher concentrations, and had an unusually high concentration of 2.4 mg/L as N. A first flush effect was observed in season 1, but was unclear in season 2. In season 1, Lathrop's ammonia loads generally made up less than 6% of the total load of the San Joaquin River with the exception of one storm event in which the city contributed 14.7% of the total load. This high load contribution was due to low flows on the San Joaquin River and high discharge flows from the city pumping stations during the storm. In season 2, loads were generally higher than in season 1. This difference was likely due to the lower river flows in season 2 which were the result of a dry water year.

For dissolved nitrate, the San Joaquin River concentrations were not significantly lower than the concentrations from the city pumping stations. There were no statistical differences in the concentrations between seasons 1 and 2; however, median concentrations increased at the San Joaquin River at Mossdale, M1 and Industrial stations.

Total nitrogen concentrations for seasons 1 and 2 combined at the San Joaquin River at Mossdale were significantly lower than those of the city pumping stations for total nitrogen. There was no statistical difference in concentrations between seasons, however the San Joaquin River at Mossdale samples were significantly lower than the pumping station samples in season 1, but not in season 2. This difference is likely due to wet versus dry water year effects or due to a small sample size. A first flush effect was seen in both seasons. Total nitrogen loads were less than 1% of the total San Joaquin River load with the exception of the first flush event in season 2 when Lathrop contributed 1.5% of the total nitrogen load on the San Joaquin River.

For both orthophosphate and total phosphorus, the San Joaquin River concentrations were significantly lower than those of the city pumping stations. The difference in distribution of the orthophosphate data between seasons 1 and 2 is likely due to wet year versus dry year effects. Season 1 concentrations for total phosphorus were significantly lower than those in season 2, which is also likely due to wet year versus dry year effects. Total Phosphorus load for all storm events was less than 3 percent. Total phosphorus also had year-to-year trends that showed evidence of a first flush effect.

Ammonia, nitrate, and total phosphorus concentrations were compared with those of other storm water studies throughout California. Lathrop's concentrations were consistently similar in comparison to other regions in the state.

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Notes

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Status and Trends

2011-2012 Yolo Bypass Fisheries Monitoring Status and Trends Report

Jared Frantzich (DWR), Jared.Frantzich@water.ca.gov, LeAnne Rojas (DWR), Leanne.Rojas@water.ca.gov, Naoaki Ikemiyagi (DWR), Naoaki.Ikemiyagi@water.ca.gov, and J. Louise Conrad (DWR), Louise.Conrad@water.ca.gov

Introduction

Largely supported by IEP, DWR has operated a fisheries and invertebrate monitoring program in the Yolo Bypass since 1998. The project has provided a wealth of information regarding the significance of seasonal floodplain habitat to native fishes. Basic objectives of the project are to collect baseline data on lower trophic levels (phytoplankton, zooplankton and aquatic insects), juvenile fish and adult fish, hydrology and physical conditions. As the Yolo Bypass has been identified as a high restoration priority by the National Marine Fisheries Service Biological Opinions for Delta Smelt (*Hypomesus transpacificus*), winter and spring-run Chinook Salmon (*Oncorhynchus tshawytscha*), and by the Bay Delta Conservation Plan (BDCP), these baseline data are critical for evaluating success of future restoration projects. In addition, the data have already served to increase our understanding of the current role of the Yolo Bypass in the life history of native fishes, and its ecological function in the San Francisco Estuary. Key findings include: (1) Yolo Bypass is a major factor regulating year class strength of splittail, *Pogonichthys macrolepidotus* (Sommer et al., 1997; Feyrer et al., 2006; Sommer et al., 2007a); (2) Yolo Bypass is a key migration corridor for adult fish of several listed and sport fish (Harrell and Sommer 2003); (3) it is one of the most important regional rearing areas for juvenile Chinook Salmon (Sommer et al., 2001a; 2005); and (4) Yolo Bypass is a source of phytoplankton to the food web of the San Francisco Estuary (Jassby and Cloern 2000; Schemel et al., 2004; Sommer et al., 2004).

This report describes the fisheries sampling effort for the 2012 water year (October 1, 2011 – September 30, 2012), as well as a summary of the fisheries catch by species and gear type. The 2011-12 sampling period yielded significantly high numbers of Delta Smelt and White Sturgeon (*Acipenser transmontanus*), as well as elevated fall chlorophyll-*a* concentrations.

Methods

Since 1998, juvenile fish have been sampled with an 8 foot rotary screw trap located in the Toe Drain approximately nine miles south of the Lisbon Weir (Figure 1) for up to seven days a week during the months of January – June. In WY2012, the rotary screw trap was operated consistently five days a week for the entire sampling period without any restrictions from high flows or heavy debris (Figure 2). For the rotary screw trap, it is possible to create rough estimations of the sampling time (total hours based on set and pull times) in order to calculate catch per unit effort (CPUE). At this time, volume of water sampled is unknown.

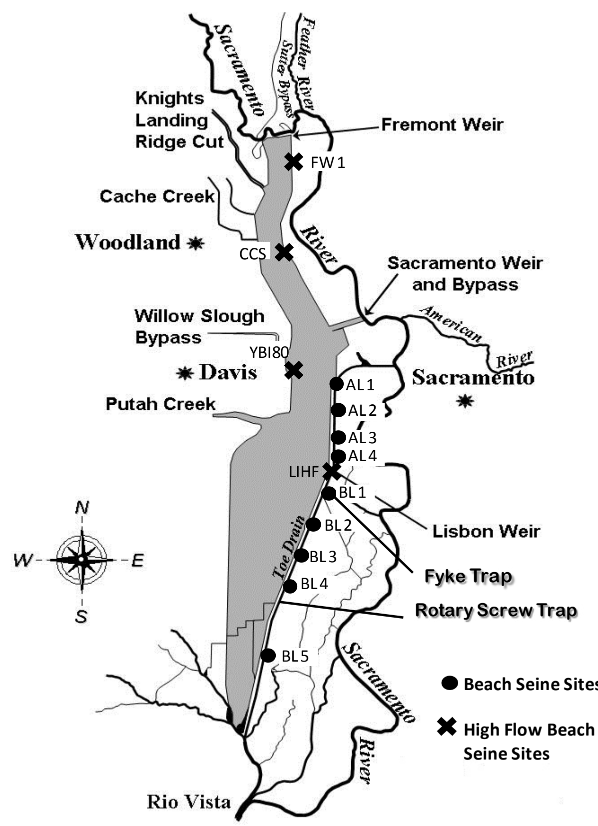

Figure 1 Map of Yolo Bypass

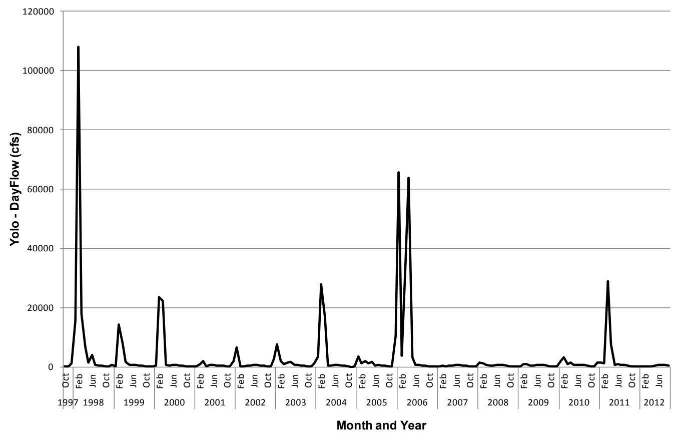

Figure 2 Average monthly Yolo Dayflow WY1998-2012

Upstream migrating, large, adult fish in the Toe Drain are monitored using a 10 foot fyke trap, designed after the Department of Fish and Wildlife's (DFW) fyke traps used for sampling sturgeon and Striped Bass in the Sacramento River. The fyke trap is operated up to seven days a week during the months of October – June (Figure 2). The trap is located ¾ of a mile below Lisbon Weir and 13 miles from the terminus of the Toe Drain (Figure 1).

We have supplemented the collection of small adult and juvenile fish in the Yolo Bypass by conducting biweekly beach seine surveys at various site locations within the Toe Drain and a perennial pond on the west side of the Bypass (Figure 1 and Figure 2). Weekly sampling is conducted during inundation periods (such as in water year 2011) at four site locations only accessible during flood conditions (Figure 1). In the summer of 2010 the beach seine survey increased to include seven additional stations, some above and below Lisbon Weir, to capture at a higher resolution of the fish assemblage above and below the weir. Dimensions of all beach seine hauls are recorded, in order to calculate catch per unit volume of water sampled.

To provide data on ambient water quality conditions, field crews collect data on several water quality parameters including: temperature, conductivity, dissolved oxygen, pH, and secchi depth. In spring 2012, the collection of turbidity was added to the routine water quality parameters. Data loggers recording water temperature at 15 minute intervals are deployed at the rotary screw trap (January – June only) and Lisbon Weir (year-round) in the Toe Drain, and for comparison purposes, in the Sacramento River at Sherwood Harbor, also year-round. In addition, chlorophyll-*a* grab samples (to estimate phytoplankton biomass), zooplankton, larval fish, and invertebrate drift samples are collected on a bi-weekly basis (weekly during inundation) at the rotary screw trap and at Sherwood Harbor.

Results and Discussion

The results for water year 2012 were highly influenced by the dry winter and spring conditions in the Sacramento Valley. The low precipitation reduced flows and availability of floodplain habitat, altering the water quality conditions and the fish species assemblage. Although there were observed reductions in the catch totals of some natives that are floodplain dependent (i.e. Sacramento Splittail and Chinook Salmon), we also documented record catches for Delta Smelt and White Sturgeon.

Hydrology

The WY2012 had the lowest winter and spring outflows since the inception of the monitoring program (Figure 3). The Sacramento Valley experienced a below-normal water year type in 2012 (based on Sacramento Valley 40-30-30 water year index) and therefore created very different hydrologic conditions within the Yolo Bypass as compared to the previous wet water year type in 2011 (CDEC, 2013). Average daily flow was 256 cubic feet per second (cfs), based on Dayflow data for flow estimates. The Dayflow flow estimates in the Yolo Bypass are calculated using combined data from the Yolo Bypass flow at Woodland, Fremont Weir spill, and South Putah Creek flow (DWR, 2012) The Fremont Weir did not crest in 2012, therefore the Yolo Bypass did not experience widespread floodplain inundation. Although, based on Lisbon Weir stage data (at stage ≥7.16 ft. the Toe Drain overbanks) the Yolo Bypass did experience some localized flooding during a few days in the spring months of January, March and April. The maximum stage at Lisbon Weir for 2012 was 7.81 ft. on January 24. The flows in the Yolo Bypass in WY2012 experience an estimated peak daily flow of 1,310 cfs on January 26 (Figure 2).

Water Quality

Water Temperature

The extreme hydrologic variability of the Yolo Bypass, with its susceptibility to floodplain inundation, can cause significant differences in the water temperature when compared with the Sacramento River. When the entire Yolo Bypass is inundated, the wetted area of the Delta is doubled (Sommer et al., 2001a), and this flooded habitat is made up of large shallow (<2m) vegetation (Sommer, 2004a). The inundation timing and duration of the Yolo Bypass varies annually, but with longer hydraulic residence times, the increased surface area of the floodplain habitat allows for warmer water temperatures to persist (Sommer et al., 2004b).

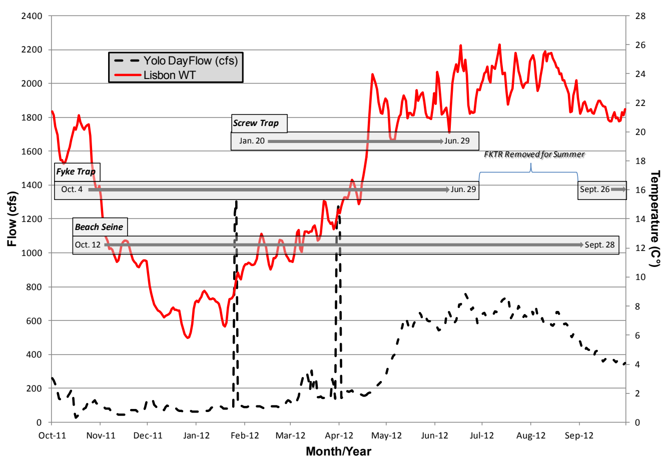

Figure 3 Fishing effort for every gear type summarized against average daily flow (source: Yolo Dayflow) and water temperature

In WY2012, water temperature on the Sacramento River at Sherwood Harbor and Yolo Bypass at Lisbon Weir followed typical seasonal trends, with the highest temperatures occurring in the summer and the lowest temperatures in the late fall and winter (Table 1). However, the Yolo Bypass experienced greater variation in maximum and minimum water temperatures that can be attributed to: (1) shallow inundated floodplain (only localized flooding in 2012), (2) lower average velocity flows, and (3) shallower and narrower channel composition of the Toe Drain as compared to the Sacramento River.

Conductivity

Conductivity is used as a surrogate measurement for the seasonal variation of salinity in the water moving through the Yolo Bypass and Sacramento River. The variations in salinity strongly affect the geographic distribution (Bulgar et al., 1993; Nobriga et al., 2008) of several listed and nonlisted fishes of the San Francisco Estuary. The discrete collection of conductance data within the Toe Drain of the Yolo Bypass at the Fyke trap site location and the Sacramento River at Sherwood Harbor occurred upon each site visit throughout the entire 2012 water year. The lowest minimum conductance values occurred in the Toe Drain during summer months in 2012, which was very different from the previous 2011 water year in which they occurred during the winter and spring time period. In general we saw significantly higher conductance values in the spring of 2012 than in 2011 (Frantzich et al., 2013). The lower conductance levels in 2011 were probably largely influenced by a greater amount of water flushing downstream into the Toe Drain from the Sacramento and various side tributaries, aiding in a greater water exchange rate throughout the perennial channel. With lower overall flows within the Sacramento River we also saw a trend of higher conductivity values throughout much of the 2012 water year. The greater variation in conductance values observed in water year 2012 in the Toe Drain of the Yolo Bypass as compared to the Sacramento River is likely due to the influence of local tributaries and various agricultural practices, including early summer and fall rice field drainage (Sommer, 2004a).

Secchi Depth

Secchi depth was recorded at the fyke trap site in the Toe Drain and in the Sacramento River at Sherwood Harbor during lower trophic sampling year-round in 2012. The average water clarity in the Toe Drain (0.23 m) is substantially lower than Sacramento River (0.82 m) year-round (Table 1). Lower water clarity is representative of a seasonally dynamic and abiotically-driven environment such as the Yolo Bypass. The seasonal hydrologic variability of the Yolo Bypass can cause reduced water clarity through increased suspended particle concentrations and higher fluctuating temperatures that can increase algal biomass (Sommer et al., 2004a). Low water clarity has shown to be beneficial to key fish species in the Delta, such as the Delta Smelt (Nobriga, 2008; Sommer and Meija 2013).

Table 1 Statistical summary of Yolo Bypass and Sacramento River at Sherwood Harbor water temperature, conductivity, and secchi depth

Month	Avg.		Min.		Max.		Std. Dev.	
Water Temperature (°C)								
	Sac	Yolo	Sac	Yolo	Sac	Yolo	Sac	Yolo
Oct	17.1	18.3	13.8	14.7	20.0	22.5	1.7	2.0
Nov	12.7	12.8	9.0	7.2	15.9	17.1	2.1	2.8
Dec	10.6	10.5	8.9	7.0	12.1	13.3	0.9	1.6
Jan	8.9	8.8	7.5	6.1	10.0	11.0	0.8	1.7
Feb	9.5	9.9	7.9	7.7	11.1	12.4	0.8	1.0
Mar	10.4	12.2	8.6	9.4	12.7	14.8	1.1	1.8
Apr	13.3	16.4	12.1	12.2	14.7	20.8	0.6	2.3
May	14.9	19.1	12.8	15.9	16.5	22.1	0.8	1.3
Jun	16.9	22.7	14.0	17.0	19.3	27.9	1.6	3.2
Jul	20.0	26.1	17.5	20.8	21.2	31.4	0.7	2.2
Aug	21.2	24.2	20.6	21.2	21.6	29.0	0.2	1.2
Sept	19.9	22.9	17.6	20.8	21.4	25.5	0.9	0.9
Conductivity (µS/cm)								
Oct	-	567	-	320	-	795	-	175
Nov	-	425	-	359	-	558	-	54
Dec	-	352	-	201	-	421	-	60
Jan	110	478	101	313	119	654	13	137
Feb	121	600	102	428	139	713	26	93
Mar	93	501	79	311	106	611	19	76
Apr	96	515	86	392	104	590	9	71
May	76	565	74	415	77	636	2	53
Jun	77	648	73	400	81	901	4	176
Jul	109	669	90	638	127	697	26	25
Aug	132	842	129	789	136	869	5	46
Sept	134	751	132	699	135	797	2	45
Secchi Depth (m.)								
Oct	-	0.23	-	0.15	-	0.32	-	0.05
Nov	-	0.24	-	0.18	-	0.34	-	0.05
Dec	-	0.27	-	0.18	-	0.70	-	0.11
Jan	0.64	0.24	0.56	0.15	0.72	0.31	0.11	0.04
Feb	0.56	0.23	0.44	0.15	0.69	0.35	0.18	0.04
Mar	0.42	0.24	0.35	0.20	0.49	0.31	0.10	0.04
Apr	0.54	0.26	0.50	0.14	0.57	0.32	0.04	0.05
May	0.94	0.23	0.93	0.15	0.96	0.29	0.02	0.04
Jun	0.87	0.24	0.82	0.13	0.96	0.30	0.08	0.04
Jul	0.91	0.32	0.74	0.20	1.08	0.63	0.24	0.17
Aug	0.86	0.20	0.84	0.12	0.89	0.27	0.04	0.08
Sept	0.87	0.24	0.86	0.20	0.88	0.27	0.01	0.03

Chlorophyll

The chlorophyll-*a* concentrations on the Sacramento River at Sherwood Harbor reached a maximum of 6.19 µg/L on February 23, 2012 and a minimum of 0.96 µg/L on November 30, 2011 (Figure 4). The chlorophyll-*a* concentration had an overall standard deviation from the mean of 1.48 µg/L. In comparison, the Toe Drain of the Yolo Bypass at the rotary screw trap reached a maximum chlorophyll-*a* concentration of 27.66 µg/L on November 2, 2011 and a minimum concentration of 3.65 µg/L on March 22, 2012 (Figure 4). The chlorophyll-*a* concentration had an overall standard deviation of the mean of 5.54 µg/L. In the Toe Drain, chlorophyll-*a* concentrations exceeded 10 µg/L (threshold for enhanced phytoplankton and cladoceran growth, Mueller-Solger et al., 2002, Schemel et al., 2004), multiple times in March, May and in fall 2012 from September – November. This is in contrast to the Sacramento River site, where no samples were collected with values exceeding 7 µg/L.

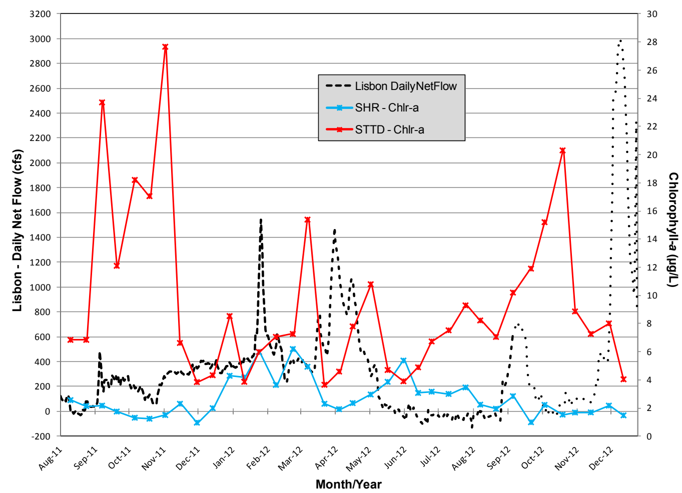

Figure 4 Chlorophyll-*a* concentration August 2011 – December 2012 at Toe Drain of Yolo Bypass and Sacramento River at Sherwood Harbor

The substantially lower values of chlorophyll-*a* in the Sacramento River are consistent with previous analyses comparing the Yolo Bypass with the Sacramento River (Sommer et al., 2004a), and likely are a result of longer residence times, greater shallow water surface area, and warmer water temperatures. In addition, nutrient inputs from agricultural drainage and small west-side tributaries may contribute to local peaks in phytoplankton production (Schemel et al., 2004). The chlorophyll-*a* trends within the Yolo Bypass for 2012 consisted of peaks in both the spring and once again in the fall, similar to the fall peak in the 2011 water year (Figure 4). Although, without prolonged floodplain inundation in 2012 we did not see near the duration or high levels that we saw in spring 2011 during floodplain drainage.

In addition to the spring peak in chlorophyll-*a*, elevated levels were also once again observed in the fall after increased flows occurred within the Toe Drain of the Bypass due to rice field drainage (Figure 4). Much like the event in 2011, a phytoplankton bloom occurred in the lower Sacramento River. These blooms are highly significant, given the generally low productivity of the Delta during the fall and the food web limitations that likely influence abundance of numerous pelagic fish species (Sommer et al., 2007). In response to the high chlorophyll-*a* values observed downstream in the Delta, a more rigorous sampling transect was completed north to south in 2012, occurring at 11 sites starting just below Knights Landing Ridge Cut and ending at Rio Vista Bridge, in an effort to investigate the hypothesis that the Yolo Bypass was the productivity source. Though sampling occurred after the initial flow pulse, results showed an obvious trend of increasing downstream chlorophyll-*a* levels at several sites as the elevated flows persisted in the Toe Drain (Figure 5). In addition, continuous chlorophyll data recorded by the DWR water quality station at Rio Vista Bridge (RVB) showed elevated levels about a month after the increased flow event in the Toe Drain (Figure 5, Mike Dempsey, DWR, unpublished data). Samples were also collected in the Sacramento River near Vieira's Harbor to provide additional certainty that chlorophyll-*a* concentrations were consistently low in the main stem during the same time period. The DWR Environmental Monitoring Program (EMP) collects phytoplankton data monthly at station D4 downstream of Rio Vista and they determined that the October bloom was dominated by the species *Aulacoseira granulate* a filamentous diatom (Tiffany Brown, DWR, unpublished data). In fall 2013, DWR Aquatic Ecology staff, in cooperation with researchers at UC Davis, Reclamation, and the Regional Water Board, will collect both phytoplankton and additional nutrient samples at an expanded suite of site locations. The objectives of the study plan are to provide a more complete spatial representation of water quality and lower trophic conditions before and after the fall rice field drainage from Yolo Bypass. Understanding the mechanisms contributing to fall phytoplankton blooms in the lower Sacramento River may provide insight into methods of active water management that may promote productivity in order to support key fisheries populations.

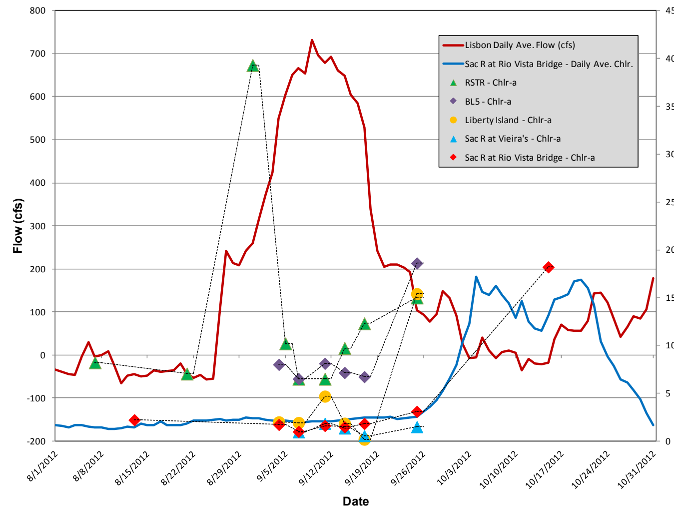

Figure 5 Chlorophyll-*a* transect data against Lisbon daily flow and RVB daily chlorophyll data

Fish

More than 40 fish species were sampled during the course of all fish sampling activities in WY2012, 15 of which are native to the San Francisco Estuary region (Table 2). The total catch of fish species from Yolo Bypass was dominated by the nonnative Inland Silverside (*Menidia beryllina*), with 20,645 sampled. The high catch of nonnative Inland Silversides in the Yolo Bypass is not surprising as they have become one of the most abundant fishes in the shallow-water habitats throughout the estuary (Moyle, 2002). In addition, the high catch in the beach seine effort in 2012 (Table 2) is consistent with high CPUE in the favorable shallow perennial channels and ponds of the Yolo Bypass that has been observed historically (Feyrer, 2004; Feyrer, 2006a; Nobriga, 2005). One of the most notable increases in abundance as compared to the previous sampling seasons was the total number of the Delta Smelt that were collected in the rotary screw trap. The WY2012 marked the highest number of Delta Smelt caught in the history of the Yolo Bypass Fisheries Monitoring Program. In addition, we experienced our highest total annual catch of White Sturgeon in the fyke trap.

Delta Smelt

The total catch of Delta Smelt in WY2012 was the highest total on record for the Yolo Bypass Fisheries Monitoring Program (Figure 6), at 160 (Table 2). The majority of this total was comprised of the adult catch in the rotary screw trap (96 adults/29 juveniles). Based on our long-term dataset the timeframe of adult Delta Smelt catch in the Yolo Bypass can occur as early as the beginning of January and can continue through June. The catch of juvenile Delta Smelt begins in May and continues through as late as July, but the presence of both year classes is variable annually and is largely affected by hydrologic conditions. In an effort to account for gaps in rotary screw trap operation in other years, we estimated the total hours of rotary screw trap operation for each sampling year, and compared the number of adult and juvenile Delta Smelt caught per sampling hour among all years of rotary screw trap operation (Figure 6). This resulted in a combined adult/juvenile catch per hour (CPH) of 1.75 Delta Smelt during the sampling period in 2012. This CPH is unprecedented, as the highest prior total was 0.74 in 2009 and the average in all years is 0.16.

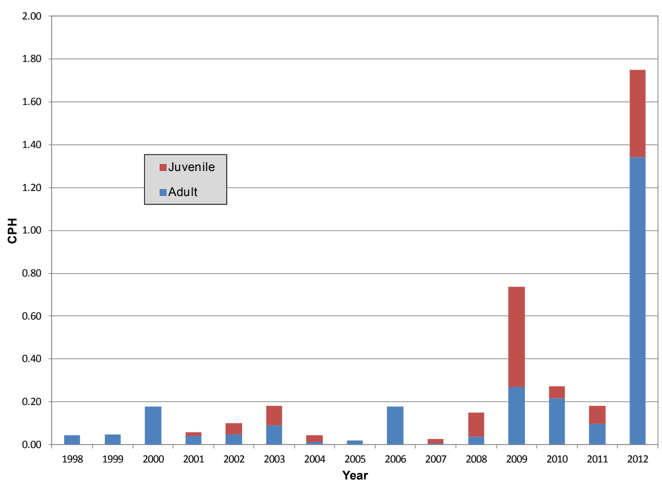

Figure 6 Rotary screw trap adult and juvenile Delta Smelt (CPH, # individuals/hour) by year since the inception of Yolo Bypass Monitoring Program

The previous highest total catch for Delta Smelt occurred in 2009, with a total of 88 fish, predominately juveniles. Notably, the Sacramento Valley water year classification types for both 2009 (dry) and 2012 (below normal) were similar, resulting in low spring outflows (CDEC, 2013). It is not known as to the exact reasons for the higher abundance of Delta Smelt in the Yolo Bypass during drier years, but possible explanations include: (1) increased upstream distribution, (2) increased numbers entering on flood tides, and (3) favorable habitat conditions. Recent findings have shown that Delta Smelt use the Cache Slough complex heavily throughout both life stages (Sommer and Meija, 2013; Sommer et al., 2011; Merz et al., 2011), and data suggests that there is a population that maintains a year-round residency within Liberty Island, just below the Toe Drain (Sommer and Meija, 2013; Sommer et al., 2011). In recent years, scientists have identified several key Delta Smelt habitat preferences that include: (1) tidal flow (Swanson et al., 1998; Sommer et al., 2011), (2) open water adjacent to habitats with long residence times (e.g. tidal marsh, shoal, low-order channels) (Sommer and Meija, 2013), (3) in or near low-salinity zone (Freyer et al., 2007; 2010 Kimmerer et al., 2009; Sommer and Meija, 2013), (4) high turbidity (>12 NTU) (Grimaldo et al., 2009), (5) water temperatures <25 °C (Swanson et al. 2000; Nobriga et al. 2008), and (6) food source primarily made up of calanoid copepods (Sommer and Meija, 2013; Sommer et al., 2011; Nobriga, 2002; Moyle, 2002). It is important to note that several of these habitat preferences can be associated with the perennial Toe Drain of the Yolo Bypass throughout much of the spring, therefore making this location desirable for Delta Smelt at multiple life stages.

White Sturgeon

The total catch of White Sturgeon in the fyke trap for WY2012 was 260 (Table 2), the highest on record for the Yolo Bypass Fisheries Monitoring Program (Figure 7). Prior to WY2012, the two years with the highest White Sturgeon catch were water years 2004 (168 total) and 2007 (120 total). Since 2000, the catch of White Sturgeon in the fyke trap has occurred predominately in the months of February, March and April during the upstream spawning migration period (Moyle, 2002; Khohlhorst, 1976, Schafter, 1997). In 2012, we saw large numbers of White Sturgeon in our fyke trap after increased spring flow pulses within the Toe Drain (Figure 7), and this has been consistent during previous years of high catch numbers. This upstream migration response by large numbers of sturgeon to spawning grounds has been observed in much of the upper Sacramento River (Schafter, 1997; Kohlhorst et al., 1991, Moyle, 2002).

It is important to note that based on angler recaptures it is thought that some sturgeon migrate upstream to lower reaches of the river in the winter months prior to making the final push to the upper reaches to spawn (Miller 1972; Kohlhorst et al., 1991; Schafter, 1997). There is limited field survey data on the seasonal use of the Cache Slough Complex by White Sturgeon, but based on the return of

DFW Sturgeon Fishing Report Cards (since 2007) there is evidence that White Sturgeon are present year-round in this northern region of the Delta, since anglers have reported catches within both the Yolo Bypass and Sacramento Deep Water Ship Channel in all seasons (DFW). It is established that many White Sturgeon migrate up the Sacramento River to spawn each year, but based on twelve years of fyke trap data collection within the Yolo Bypass, some portion of the population moves up the Toe Drain, which has no fish passage to the main stem during dry years when Fremont Weir is not spilling. Even in years of high flows White Sturgeon are susceptible to stranding at the various flood control structures in the Yolo Bypass (Thomas et al., 2013), and therefore it has been a focus of the BDCP to develop a better method of fish passage at Fremont Weir to allow White Sturgeon to reach viable spawning grounds in the upper Sacramento and Feather rivers.

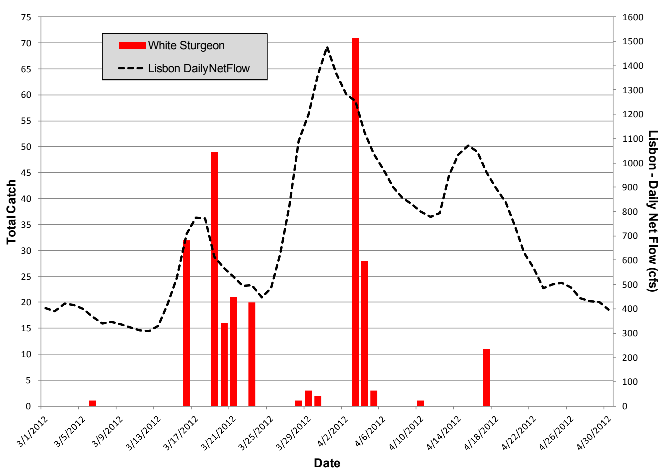

Figure 7 Fyke trap total catch of White Sturgeon for WY2012 against Lisbon Weir Daily Net Flow

As part of the DFW Ecosystem Restoration Program (ERP) and IEP-funded project "Evaluation of Floodplain Rearing and Migration in the Yolo Bypass," 67 White Sturgeon from the fyke trap were tagged surgically with Vemco V16 acoustic tags. This telemetry study is a joint effort by the UC Davis Biotelemetry Lab and the DWR Aquatic Ecology Section to investigate White Sturgeon holding behavior as well as residence and migration timing in the Yolo Bypass. It is the primary goal of the project to provide additional insight into fish behavior once adult White Sturgeon and Chinook Salmon enter the Yolo Bypass, with an emphasis on guiding restoration plans in developing solutions to improve future fish passage to the Sacramento River under variable hydrologic conditions.

Table 2 Species catch summarized by gear type for WY2012. Sorted by descending order of abundance

Species	*Screw Trap*	*Fyke Trap*	*Beach Seine*	*Total Catch*
Inland Silverside	5,649 (50.20%)	2 (0.09%)	14,994 (56.49%)	20,645
Threadfin Shad	2,650 (23.55%)	64 (2.91%)	2,125 (8.01%)	4,839
Bluegill	14 (0.12%)	2 (0.09%)	2914 (10.98%)	2,930
Striped Bass	1,180 (10.49%)	367 (16.68%)	317 (1.19%)	1,864
Bigscale Logperch	1 (0.01%)	0	1647 (6.20%)	1,648
Black Bullhead	0	15 (0.68%)	1,013 (3.82%)	1,028
Splittail	706 (6.27%)	151 (6.86%)	61 (0.23%)	918
Western Mosquitofish	86 (0.76%)	0	824 (3.10%)	910
Black Crappie	39 (0.35%)	110 (5%)	741 (2.79%)	890
White Catfish	159 (1.41%)	724 (32.91%)	5 (0.02%)	888
Shimofuri Goby	164 (1.46%)	0	569 (2.14%)	733
Common Carp	125 (1.11%)	163 (7.41%)	140 (0.53%)	428
Channel Catfish	49 (0.44%)	235 (10.68%)	35 (0.13%)	319
White Sturgeon	0	259 (11.77%)	0	259
White Crappie	2 (0.02%)	7 (0.32%)	217 (0.82%)	226
Fathead Minnow	19 (0.17%)	0	163 (0.61%)	182
Largemouth Bass	6 (0.05%)	1 (0.05%)	175 (0.66%)	182
Delta Smelt	125 (1.11%)	0	35 (0.13%)	160
Prickly Sculpin	33 (0.29%)	0	114 (0.43%)	147
Chinook Salmon	119 (1.06%)	4 (0.18%)	20 (0.08%)	143
Yellowfin Goby	15 (0.13%)	0	93 (0.35%)	108
Tule Perch	20 (0.18%)	0	75 (0.28%)	95
Sacramento Blackfish	0	21 (0.95%)	59 (0.22%)	80
Warmouth	1 (0.01%)	0	76 (0.29%)	77
Threespine Stickleback	53 (0.47%)	0	0	53
American Shad	1 (0.01%)	35 (1.59%)	13 (0.05%)	49
Sacramento Sucker	0	31 (1.41%)	9 (0.03%)	40
Redear Sunfish	0	0	39 (0.15%)	39
Golden Shiner	17 (0.15%)	1 (0.05%)	12 (0.05%)	30
Hitch	1 (0.01%)	2 (0.09%)	25 (0.09%)	28
Green Sunfish	0	0	15 (0.06%)	15
Sacramento Pikeminnow	1 (0.01%)	2 (0.09%)	11 (0.04%)	14
Pacific Lamprey	9 (0.08%)	0	0	9
Goldfish	1 (0.01%)	3 (0.14%)	2 (0.01%)	6
Longfin Smelt	4 (0.04%)	0	0	4
Spotted Bass	0	0	3 (0.01%)	3
Red Shiner	1 (0.01%)	0	1 (0%)	2
Wakasagi	1 (0.01%)	0	1 (0%)	2
Pacific Staghorn Sculpin	0	0	1 (0%)	1
Rainbow / Steelhead Trout	0	1 (0.05%)	0	1
Smallmouth Bass	1 (0.01%)	0	0	1
Grand Total	11,252	2,200	26,544	39,996

Future Work

In spring of 2013 DWR, UC Davis, and U.S. Bureau of Reclamation (USBR) continued the ERP project. This project will focus on acoustic telemetry technology to understand movement patterns of adult salmon and sturgeon, as well as juvenile salmon migration patterns and residence times in the Yolo Bypass, genetics to determine run classifications of Chinook Salmon that use the Yolo Bypass, and investigate the possibility of an isotopic signature of Yolo Bypass residence on the otoliths of juvenile salmon. In addition, the project supports the analysis of more than a decade of data on lower trophic organisms and juvenile salmon usage of the Yolo Bypass. Also in 2013, DWR added a work plan item to further investigate fall phytoplankton production in the Toe Drain of the Yolo Bypass and to determine timing of downstream export.

Acknowledgements

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2012 20 mm Survey

Lauren Damon, DFW, Lauren.Damon@wildlife.ca.gov

The California Department of Fish and Wildlife (CDFW) staff conducts the 20 mm Survey annually to monitor the distribution and relative abundance of larval and juvenile Delta Smelt (*Hypomesus transpacificus*) in the upper San Francisco Bay Estuary. The survey began in 1995 and supplies real-time catch data to water and wildlife managers as part of an adaptive management strategy to limit the risk of entrainment to Delta Smelt from water exports.

From March to July of 2012, staff completed nine bi-weekly surveys. A total of 47 stations (Figure 1) were sampled each survey to measure larval fish and zooplankton densities. Larval fish were collected using a conical net with 1600-micron mesh. The 20 mm net is 5.1 meters long with a mouth area of 1.51 square meters, and is attached to a rigid steel D-ring frame that is mounted on skis. At each station, the entire water column was sampled using three stepped-oblique tows. A zooplankton tow was also simultaneously collected. All samples were preserved in 10% buffered and dyed formalin for later identification in the laboratory.

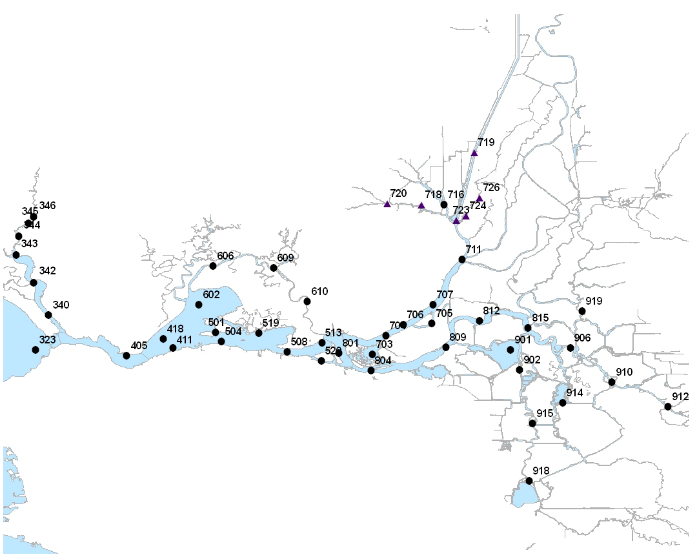

Figure 1 The CDFW 20 mm Survey station map, showing current sampling station locations in the upper Sacramento-San Joaquin Estuary. Stations marked with a black dot are core stations, stations marked with a purple triangle are non-core stations.

A total of 52,420 fish (42 taxa) were collected in 2012. Delta Smelt was the sixth most abundant species, making up about 2% of the total catch (Table 1). Larval and juvenile Delta Smelt catches were relatively low during March and April, increased in early May, and peaked in late May (Survey 6; n=441) providing the highest catch per survey since 2001. Delta Smelt catch decreased but remained relatively high in early June, and then dropped off for the final two surveys in June and July. This decrease has been apparent during prior 20 mm Survey seasons, as the larger juveniles are no longer efficiently retained in the net (Figure 2).

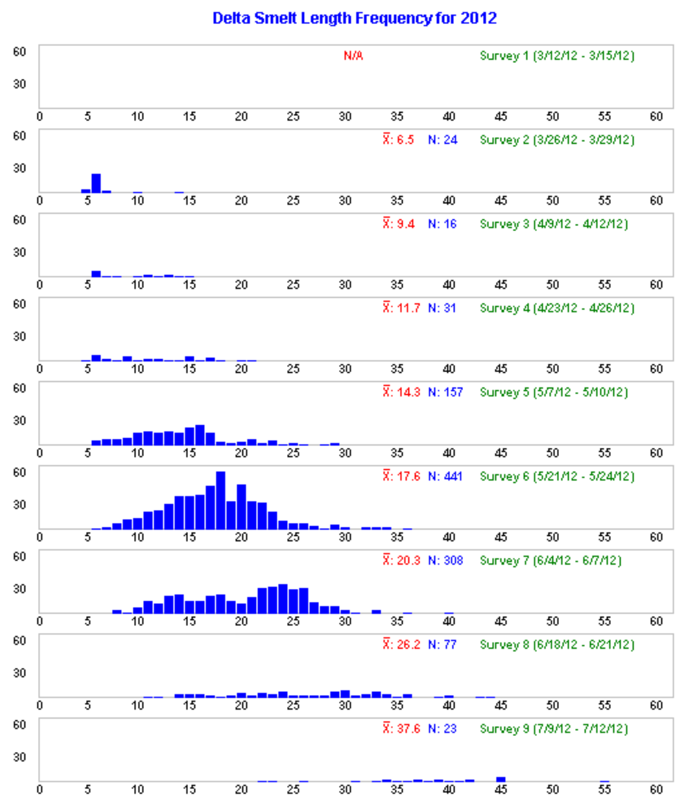

Figure 2 Delta Smelt length frequency distributions from the CDFW 2012 20 mm Survey (http://dfg.ca.gov/delta/data/20mm/Length_frequency.asp)

The first Delta Smelt larvae were caught at the end of March (Survey 2) and ranged in size from 5 to 14 millimeters, indicating that spawning had begun by early March. The last newly-hatched larvae were caught in May, indicating an end to the spawning season (Figure 2). Larval Delta Smelt were found throughout the estuary, including the confluence, Montezuma Slough, and the Napa River (Figure 3). It is likely that adult Delta Smelt used these same locations within the estuary to spawn, as mature adults were caught during the same time period in the CDFW's Delta Smelt spawner survey (Spring Kodiak Trawl).

Table 1 Total species caught from the 2012 CDFW 20 mm Survey

Common Name	*n*	*% Catch*
Tridentiger spp.	19,253	36.73%
Pacific Herring	12,869	24.55%
Striped Bass	9,811	18.72%
Longfin Smelt	3,543	6.76%
Northern Anchovy	1,291	2.46%
Delta Smelt (YOY)	1,077	2.05%
Delta Smelt (adults)	62	0.12%
Yellowfin Goby	1,112	2.12%
Bay Goby	956	1.82%
Prickly Sculpin	846	1.61%
American shad	438	0.84%
Threadfin Shad	360	0.69%
Arrow Goby	252	0.48%
White Catfish	112	0.21%
Three Spine Stickleback	94	0.18%
Jacksmelt	42	0.08%
Cyprinids (unid)	33	0.06%
Shimofuri Goby	31	0.06%
Pacific Staghorn Sculpin	30	0.06%
Centrarchids (unid)	28	0.05%
Chinook Salmon	24	0.05%
Wakasagi	22	0.04%
Inland Silverside	21	0.04%
Longjaw Mudsucker	21	0.04%
Bigscale Logperch	17	0.03%
Splittail	15	0.03%
Carp	11	0.02%
Sacramento Sucker	11	0.02%
Starry Flounder	6	0.01%
Shokihaze Goby	6	0.01%
English Sole	5	0.01%
Black Crappie	3	0.01%
Topsmelt	3	0.01%
Channel Catfish	3	0.01%
Rainwater Killifish	2	<0.01%
Bay Pipefish	2	<0.01%
Tule Perch	2	<0.01%
Mosquitofish	1	<0.01%
Goldfish	1	<0.01%
Sacramento Blackfish	1	<0.01%
Lampreys (unid)	1	<0.01%
White Croaker	1	<0.01%
Cheekspot Goby	1	<0.01%

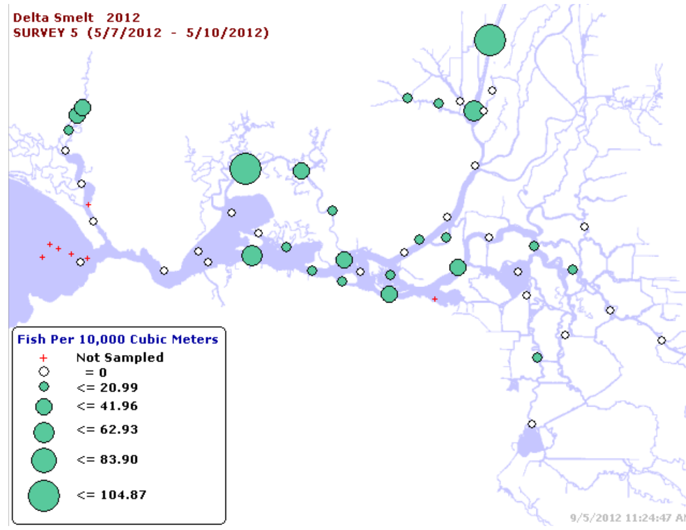

Figure 3 Delta Smelt distribution map from CDFW 20 mm Survey 5 (taken from http://dfg.ca.gov/delta/projects.asp?ProjectID=20mm). Green bubbles represent the relative CPUE of YOY Delta Smelt at each site (see legend). White bubbles are sampled stations with no YOY Delta Smelt caught. Red crosses indicate the station was not sampled (these stations are not part of our current surveys).

An index of abundance for larval/juvenile Delta Smelt is calculated using data from the four surveys around which the mean size of young of the year (YOY) Delta Smelt is 20 mm. The index is calculated using only the 41 core stations, which have been sampled consistently since the survey's inception. The 2012 index was 11.1 and was calculated using Surveys 5 (May) through 8 (June). This year's index is the eighth highest on record, and the highest index since 2005 (Figure 4). The increase in the relative abundance of larval and juvenile Delta Smelt in 2012 was likely due to the wet 2010/2011 water year, which provided relatively good conditions for adult Delta Smelt recruitment, development, and spawning.

Fish distribution maps, length distributions, and catch per unit effort (CPUE) by station for the current and previous years are reported on the 20 mm Survey webpage (http://dfg.ca.gov/delta/projects.asp?ProjectID=20mm). Existing data and metadata can be found at our FTP site (ftp://ftp.dfg.ca.gov/Delta%20Smelt/) and detailed methods on the calculation of the 20 mm abundance index are available through this author.

Year	Index
1995	4.4
1996	33.9
1997	19.3
1998	7.7
1999	39.7
2000	23.8
2001	11.3
2002	8.0
2003	13.1
2004	8.2
2005	15.4
2006	9.9
2007	1.0
2008	2.9
2009	2.3
2010	3.8
2011	8.0
2012	11.1

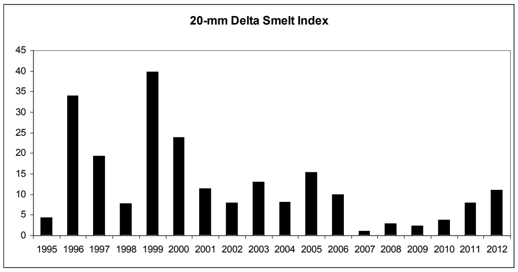

Figure 4 The annual index of abundance for YOY Delta Smelt for the historical record of the CDFW 20 mm Survey

Specific-Conductance and Water Temperature Data, San Francisco Bay, California, for Water Years 2008-10

Paul A. Buchanan (USGS), buchanan@usgs.gov

Introduction

The U.S. Geological Survey (USGS) has continuously monitored specific conductance (a surrogate that can be converted to salinity) and temperature in San Francisco Bay since 1989 and these data are a valuable resource for the San Francisco Estuary community. This monitoring is part of the Interagency Ecological Program to comply with Order 10 of Water Rights Decision 1485. Delta outflow is a key driver affecting Bay habitat (salinity) and circulation, including flushing of South San Francisco Bay (McCulloch et al. 1970, Shellenbarger et al. 2013). These data provide the basis for calibrating and validating many numerical models of San Francisco Bay used to design development projects and restore wetlands, including the Napa/Sonoma Marsh Restoration, Hamilton Airfield Restoration, dredged material disposal studies, San Francisco Airport Runway Expansion, Bair Island Restoration, South Bay Salt Pond Initial Stewardship Plan, and the South Bay Salt Pond Restoration Project. The data have been analyzed to determine the effect of flow diversions on Bay salinity (Shellenbarger and Schoellhamer 2011) and used as ancillary data by many other studies. The salinity stations are part of a larger continuous monitoring program that includes suspended-sediment concentration monitoring supported by the U.S. Army Corp of Engineers as part of the Regional Monitoring Program for Water Quality in the San Francisco Estuary and other agencies (Schoellhamer et al. 2007).

This article presents time-series graphs of specific-conductance and water-temperature data collected in San Francisco Bay during water years 2008-10 (October 1, 2008, through September 30, 2010). Specific-conductance and water-temperature data were recorded at 15-minute intervals at five USGS locations (Figure 1, Table 1).

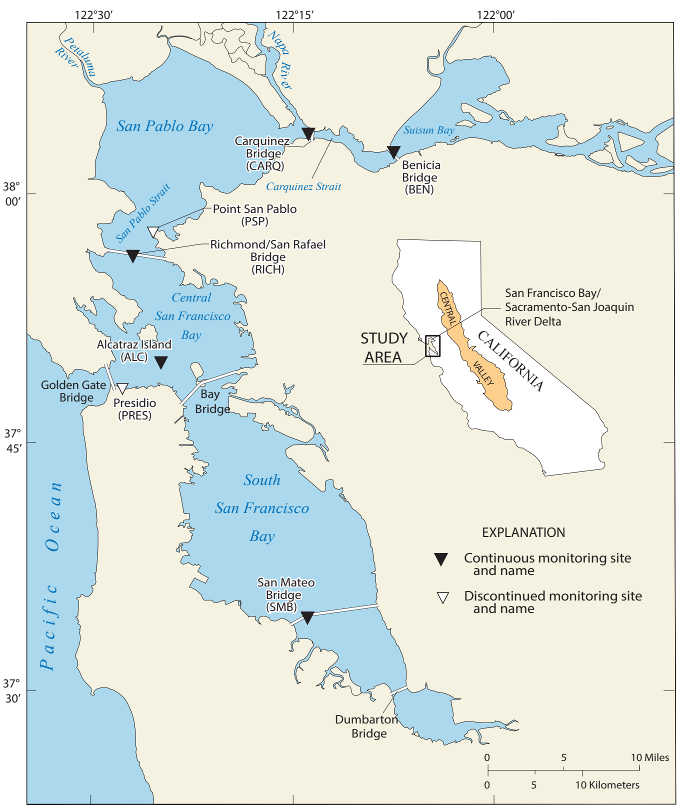

Figure 1 Location of continuous monitoring sites in San Francisco Bay, California

Specific-conductance and water-temperature data from monitoring station San Francisco Bay at San Mateo Bridge (SMB) were recorded by the California Department of Water Resources (DWR) before 1988, by the USGS National Research Program from 1988 to 1989, and by the USGS-DWR cooperative program since 1990. Monitoring stations Suisun Bay at Benicia Bridge (BEN) and Carquinez Strait at Carquinez Bridge (CARQ) were established in 1998 by the USGS. The monitoring station at San Francisco Bay at Alcatraz Island (ALC) was established in 2003 by the USGS to replace the discontinued monitoring station San Francisco Bay at Presidio Military

Reservation. Monitoring station San Francisco Bay at Richmond/San Rafael Bridge (RICH) was established in 2006 by the USGS to replace the discontinued monitoring station San Pablo Strait at Point San Pablo.

Data Collection

Specific-conductance and water-temperature data were collected at two depths in the water column (Table 1) to help define the vertical variability. However, at the shallow ALC site, data were collected only at one depth.

Table 1 Sensor depths (in feet) below mean lower-low water1 (MLLW), San Francisco Bay, California, water years 2008-2010

Site	*Code*	*Station No.*	*Lat. (NAD 1983)*	*Long. (NAD 1983)*	*Sensor depth*	*Depth below MLLW*[1]	*MLLW depth*
Suisun Bay at Benicia Bridge, near Benicia, Ca.	BEN	11455780	38° 2'42"	122° 7'36"	Near-surface	6	80
					Near-bottom	55	
Carquinez Strait at Carquinez Bridge, near Crockett, Ca.	CARQ	11455820	38° 3'41"	122° 13'32"	Mid-depth	40	88
					Near-bottom	83	
San Francisco Bay at Richmond/ San Rafael Bridge near San Rafael, Ca.	RICH	3756071 22264701	37° 56'07"	122° 26'47"	Mid-depth	15	45
					Near-bottom	40	
San Francisco Bay at NE shore Alcatraz Island, Ca.	ALC	3749381 22251801	37° 49'38"	122° 25'18"	Mid-depth	6	16
San Francisco Bay at San Mateo Bridge, near Foster City, Ca.	SMB	11162765	37° 35'04"	122° 15'03"	Near-surface	4	48
					Near-bottom	38	

[1] The mean lower-low water depth is the average of the lower-low water height above bottom of each tidal day observed during the National Tidal Datum Epoch (NTDE). The NTDE is the specific 19-year period (1960-1978 for values given in this report) adopted by the National Ocean Service as the official time segment during which tidal observations are made and reduced to obtain mean values (National Oceanic and Atmospheric Administration, 2000).

Several types of instrumentation were used to measure specific-conductance and water temperature data in San Francisco Bay. Specific conductance, reported in microsiemens per centimeter at 25 °Celsius (C), was measured using either a Foxboro electrochemical analyzer (calibrated accuracy ± 0.5%) or a YSI, Inc. 6920-M multi-parameter water quality logger (conductivity cell calibrated accuracy ± 0.5%). Water temperature (reported in degrees Celsius) was measured using a Campbell Scientific thermister (accuracy ± 0.2 °C), or a YSI 6920-M multi-parameter water quality logger (temperature probe accuracy ± 0.2 °C). The calibrated accuracies stated here are manufacturer specifications and do not reflect the accuracy of collected data. In an environmental monitoring program, potential sources of introduced error include, but are not limited to, electronic drift, calibration standard inconsistencies, and biological fouling of sensors.

Monitoring instrument calibrations were checked every 3-4 weeks. Calibration of the Foxboro specific-conductance instruments were checked using a WTW model 197 conductivity meter (calibrated accuracy ± 1%) which was calibrated to a known specific-conductance standard. Direct checks against a known standard were not possible with the Foxboro large-bore probe because of the large volume of standard needed. Calibration of the YSI, Inc. specific-conductance instrument was checked using a range of known specific-conductance standards. Calibration of the water-temperature instruments were checked using a NIST traceable Cole Parmer thermister (accuracy ± 0.2 °C). Data corrections (necessary because of biological fouling or instrument electronic drift) were applied to the record following the guidelines described by Wagner and others (2000).

Data Presentation

Figures 2 through 6 show time-series graphs of the specific-conductance and water-temperature data measured at the five sites in San Francisco Bay. Gaps in the data primarily are caused by equipment malfunctions and fouling. Tidal variability (ebb and flood) affects specific conductance and water temperature (Cloern and others, 1989; Ruhl and Schoellhamer, 2001). To illustrate tidal variability, Figure 7 shows the near-surface and near-bottom specific conductance and the corresponding water-level data at the BEN site for the 24 hours of December 31, 2009. The water-level data are not published or referenced to a known datum and are shown only to detail how specific conductance varies with tidal change. Tidal variability is greater in Carquinez Strait than in South San Francisco Bay (Figures 2, 3, 6; Schoellhamer, 1997).

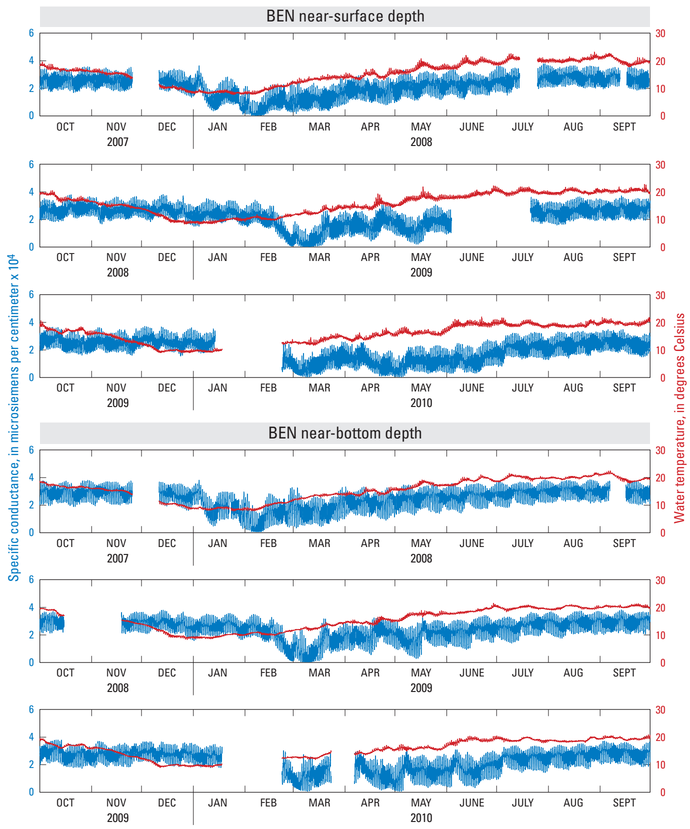

Figure 2 Measurements of specific conductance and water temperature at Benicia Bridge (BEN), Suisun Bay, water years 2008-2010. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104)

Daily maximum and minimum values of specific-conductance and water-temperature data for the five sites are published annually in the USGS Water Resources Data, California, series, which is available on the USGS website http://ca.water.usgs.gov/archive/waterdata/ (USGS, accessed June 1, 2011). The complete data sets through September 30, 2010, also are available [http://sfbay.wr.usgs.gov/sediment/cont monitoring/index.html](http://sfbay.wr.usgs.gov/sediment/cont_monitoring/index.html) (USGS, accessed June 1, 2011).

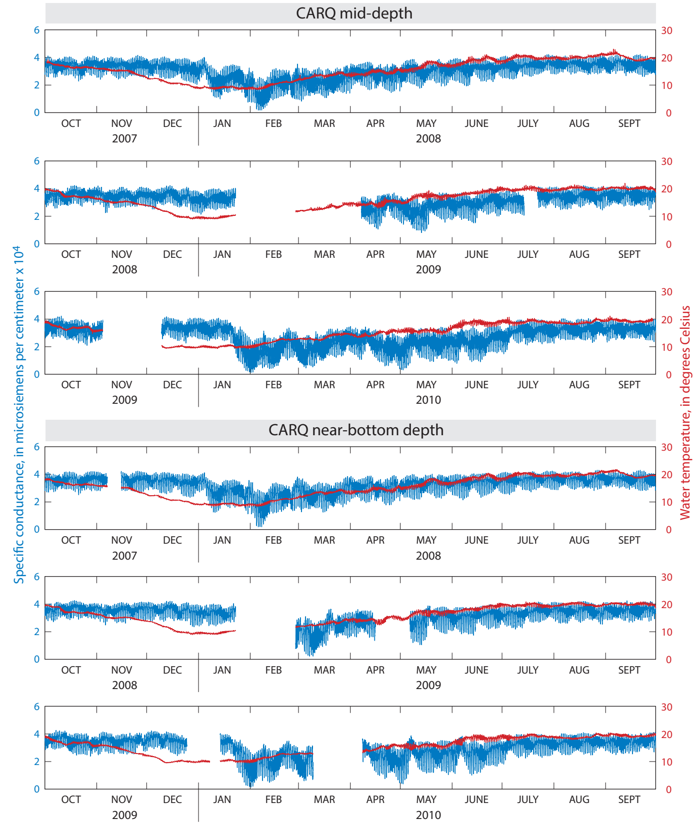

Figure 3 Measurements of specific conductance and water temperature at Carquinez Bridge (CARQ), Carquinez Strait, water years 2008-2010. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104)

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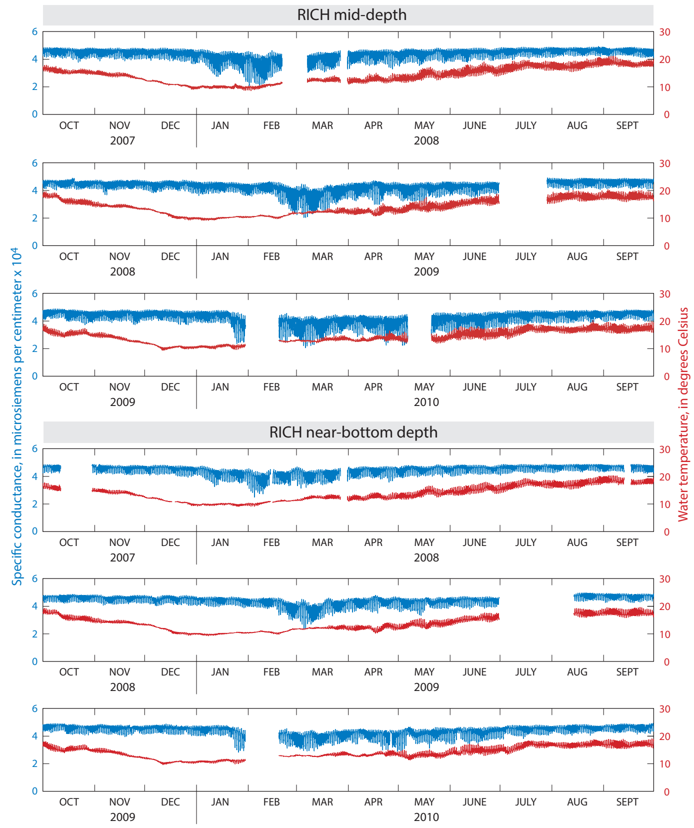

Figure 4 Measurements of specific conductance and water temperature at Richmond/San Rafael Bridge (RICH), Central San Francisco Bay, water years 2008-2010. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104)

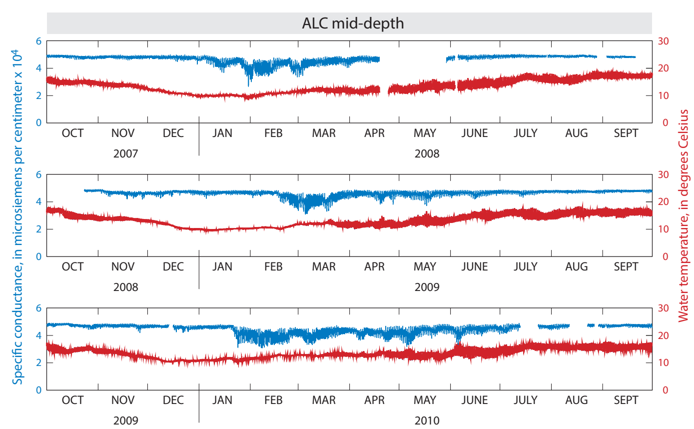

Figure 5 Measurements of specific conductance and water temperature at Alcatraz Island (ALC), Central San Francisco Bay, water years 2008-2010. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104)

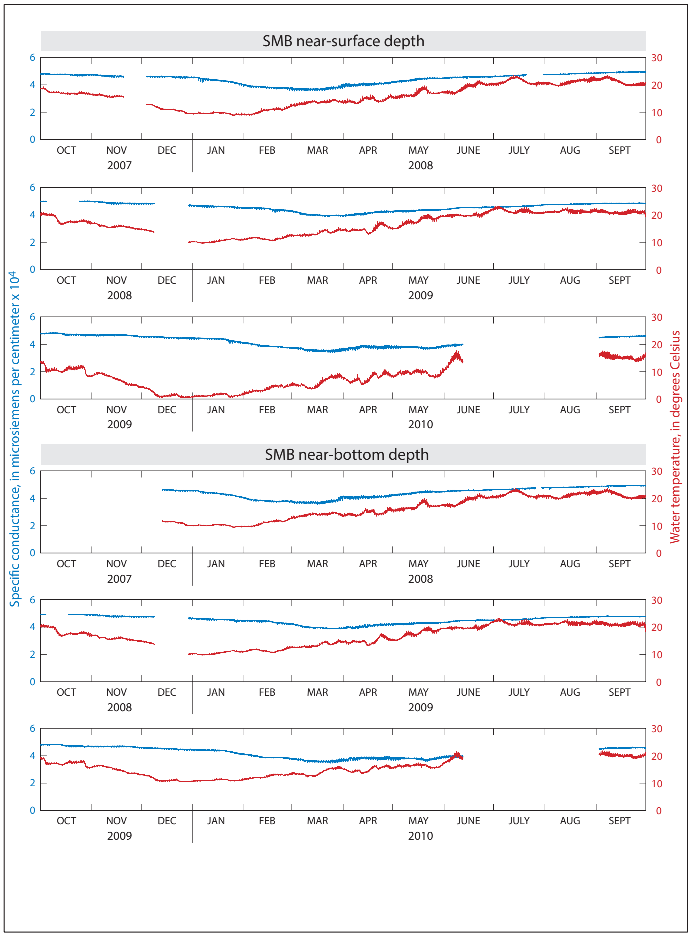

Figure 6 Measurements of specific conductance and water temperature at San Mateo Bridge (SMB), South San Francisco Bay, water years 2008-2010. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104)

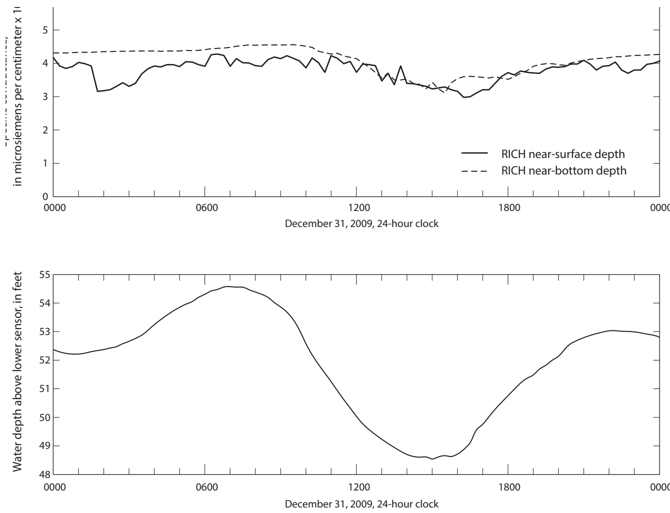

Figure 7 Near-surface and near-bottom measurements of specific conductance and water levels at Benicia Bridge, Suisun Bay, December 31, 2009. For reference, seawater has a specific conductance of about 53,000 microsiemens per centimeter (5.3 x 104).

■ Interagency Ecological Program for the San Francisco Estuary ■

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